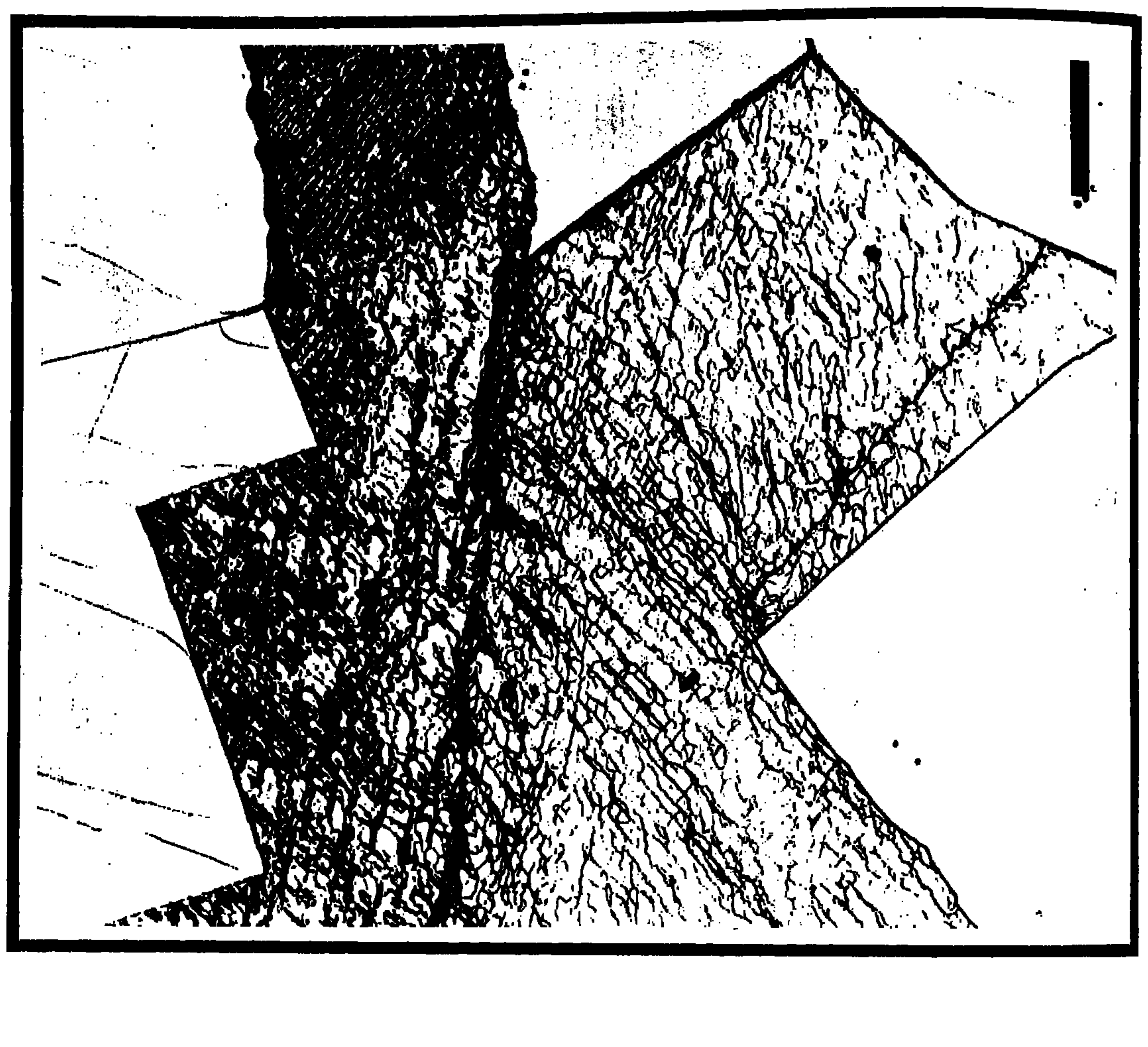
EOS
Transactions, American Geophysical Union
Vol. 65 No. 47 November 20, 1984



Eos, Transactions, American Geophysical Union Vol. 65, No. 47, Pages 1185–1192 November 20, 1984

Mineralogy, Petrology, and Crystal Chemistry

4230 Experimental Mineralogy and Petrology
EXPERIMENTAL METHODS FOR QUENCHING STRUCTURES IN LUNAR-ANALOG SILICATE MELTS: VARIATIONS AS A FUNCTION OF QUENCH MEDIA AND COMPOSITION
M. D. Dyar (Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology Cambridge, Massachusetts 02139)

Compositions analogous to lunar green, orange, and brown glasses were synthesized under consistent conditions, then quenched into a variety of different media when the samples were removed from the furnace. Iron valence and coordination are a direct function of quench media used, spanning the range from brine/ice (most effective quench), water, butyl phthalate, silicone oil, liquid nitrogen, highly reducing CO-CO_2 gas, to air (least efficient quench). In the green and brown glasses, Fe^{3+} in four- and six-fold coordination is observed in the slowest quenched-samples; Fe^{2+} coordination varies directly with quench efficiency. Less pronounced changes were observed in the Ti-rich orange glass. Therefore the remote-sensed spectrum of a glass-bearing regolith on the Moon may be influenced by the process by which the glass cooled, and extreme caution must be used when comparing spectra of synthetic glass analogs with real lunar glasses. (Mossbauer, lunar glasses, quenching).

J. Geophys. Res., B, Paper 4B5805.

4230 Experimental Mineralogy and Petrology
A TRANSIENT HEATING EVENT IN THE HISTORY OF A HIGHLANDS TROCTOLITE FROM APOLLO 12 SOIL 12033
Ursula B. Marvin (Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts, 02138), and David Walker

A 1.5 mm clast of troctolite attached to a glassy, alkali-rich soil breccia was identified in a thin section of 1-2 mm particles from Apollo 12 soil sample 12033. The troctolite consists of unzoned, euhedral to subhedral olivines (Fo_{88}) in a groundmass of granulitic plagioclase (An_{95}). The composition identifies the troctolite as a member of the Mg-rich plutonic suite of norites-troctolites-dunites from the lunar highlands. Each olivine grain is rimmed by a thin selvage of olivine-plagioclase glass containing vesicles and minute crystallites of spinel, olivine, and plagioclase. This unique texture records a complex history of events, in- [illegible]

J. Geophys. Res., B, Paper [illegible]

4760 Petrogenesis
TWO-STAGE MODELS FOR LUNAR AND TERRESTRIAL ANORTHOSITES: PETROGENESIS WITHOUT A MAGMA OCEAN
John Longhi (Department of Geology & Geophysics, Yale University, Box 6666, New Haven, CT 06511) and Lewis D. Ashwal

Two-stage diapiric models for lunar ferroan anorthosites and terrestrial massif anorthosites are examined. The lunar model is developed to explain early lunar differentiation in the absence of a magma ocean. If correct, the terrestrial model serves as an analog for the development of lunar anorthositic diapirs. There is field and textural evidence of transport of mostly crystalline anorthositic material within the terrestrial complexes. This evidence, combined with the absence of anorthositic lavas and phase equilibrium constraints inhibiting the production of hyperaluminous magmas, is consistent with the detachment of plagioclase-rich crystalline mushes from large, uppermost mantle plutons and multiple diapiric intrusion of those mushes into the upper sialic crust with attendent anatexis. Rudimentary dynamical calculations suggest that a simple, single-layer source for the diapirs is improbable: either there were several parental magma chambers or there was a single large chamber that was repeatedly replenished. The lunar model is a development of Wetherill's (1975) suggestion that, following accretion, the outer portion of the moon consisted of a stack of overlapping layered intrusions and that reheating of these intrusions mobilized their anorthositic layers, which intruded upwards to produce the anorthositic lunar crust. Dynamical calculations show that gravitational instabilities in anorthositic layers ($\leq$1 km thick) could develop into diapirs on a reasonable time scale (50-100 m.y.) only if the outer portion of the moon was partially remelted. We suggest that partial melting of the interior due to the decay of long-lived radionuclides with the subsequent onset of global convection heated the stack of intrusions from below, thus causing melting and allowing the anorthositic diapirs to grow and ascend fairly rapidly. As the convecting zone thickened, a mass expulsion of anorthositic material out of the lunar interior may have occurred.

J. Geophys. Res., B, Paper 4B5821.

Particles and Fields—Interplanetary Space

5320 Cosmic ray effects in meteorites and terrestrial matter
6530 Gross properties of planets
THE SECONDARY RADIATION UNDER SATURN'S A-B-C RINGS PRODUCED BY COSMIC RAY INTERACTIONS
J. F. Cooper, J. H. Eraker and J. A. Simpson (Enrico Fermi Institute, University of Chicago, Chicago, Illinois, 60637)

From measurements on the Pioneer 11 spacecraft electrons and protons under Saturn's A-B-C rings were reported by Simpson et al., (Science, 207, 411, 1980) and Chenette et al. (JGR, 85, 5785, 1980) and identified as the secondary products of cosmic ray nucleons with energies > 10 GeV interacting with ring matter. We have extended their analysis and have also found both secondary gamma ray fluxes with energies > 15 MeV and fragmentation nuclei (H and heavier nuclei) with energies < 10 MeV/N, which are consistent with this interpretation. From a comparison of the measured low energy proton and gamma ray fluxes with fluxes from numerical simulations of the secondary particle production and propagation in material slabs (protons) and the Earth's atmosphere (gamma rays), we find the A-B-C ring mean surface density, $\langle\sigma\rangle$ (g/cm^2) sampled along the trajectory of Pioneer 11 is 50^{+30}_{-20} g/cm^2. Direct measurement of the A-B-C ring surface density, σ, in radial intervals of 300-1000 km is obtained from the measured higher energy secondary particles (electrons > 25 MeV and protons > 67 MeV). The surface density of the optically thick B ring is measured for the first time. Two analyses with separate data sets yield a surface density for the B ring of 90^{+70}_{-46} g/cm^2 and 82 ± 25 g/cm^2. The latter value yields a B ring mass of $1.0 \pm 0.4 \times 10^{22}$ g. We obtain a value for the A-B-C ring mass of $2.7^{+1.0}_{-0.6} \times 10^{-8}$ M_S, where M_S (Saturn's mass) = 5.7×10^{29} g. Our surface density measurements are shown to be consistent with results derived from Voyager ring radio/optical opacity measurements and the observed damping of density waves in the ring.

J. Geophys. Res., A, Paper 4A8093

Christian Doppler and the Doppler Effect

Kurt Toman
Propagation Branch, Rome Air Development Center, Electromagnetic Sciences Division, Hanscom AFB, MA 01731

A summary is given of Doppler's life and career. He was born 180 years ago on November 29, 1803, in Salzburg, Austria. He died on March 17, 1853 in Venice. The effect bearing his name was first announced in a presentation before the Royal Bohemian Society of the Sciences in Prague on May 25, 1842. Doppler considered his work a generalization of the aberration theorem as discovered by Bradley. With it came the inference that the perception of physical phenomena can change with the state of motion of the observer. Acceptance of the principle was not without controversy. In 1852, the mathematician Petzval claimed that no useful scientific deductions can be made from Doppler's elementary equations. In 1860, Ernst Mach resolved the misunderstanding that clouded this controversy. The Doppler effect is alive and well. Its role in radio science and related disciplines is enumerated.

Historical Background

The astronomer Olaf Roemer determined the velocity of light in 1676 (Table 1) from time interval measurements [*Cohen*, 1939]. These intervals involved eclipses of the moons of Jupiter by the planet. Roemer made the important observation that the 42.5-hour orbital period of Jupiter's innermost moon, Io, measured between successive immersions and emersions from Jupiter's shadow, appeared shorter when the earth approached Jupiter and longer when it receded from Jupiter. In effect, Roemer used a Doppler method in determining the velocity of light [*Gill*, 1965]. In 1727, Bradley attempted to use the earth's orbit as a baseline for determining the distance to the nearest stars by triangulation [*Bradley and Halley*, 1728]. Though failing in this effort, Bradley discovered the phenomenon of aberration: that is, the elevation angle at which a star is seen varies with the relative speed of the observer.

In both studies the orbital motion of the earth played an important role. In Roemer's study the time intervals shortened when the observer approached Jupiter and lengthened when he receded. In Bradley's study the elevation angle to a star changed with the observer's speed. While *Doppler* [1843] barely mentioned Roemer's work, he cited Bradley's aberration theorem, claiming that his own study was a generalization of Bradley's discovery. Doppler stated his principle in simple terms: An observer on a boat moving toward approaching water waves perceives shortened wave periods; moving with the waves, longer ones. He postulated that the colors of stars are the result of their motion relative to the earth and asserted that "if the orbital speed of the earth would be 10 times its actual value, all fixed stars in the eastern part of the ecliptic would, without exception, appear blue or green, those in the west orange or red." How did Doppler arrive at this postulate? It seems that he was deeply committed to the idea that the colors of stars are determined by their motion. He also spoke of enhanced retrograde motion that could make stars invisible and an enhancement in an observer's approaching motion that could render stars visible. Following the younger Herschel, Doppler saw the totality of light sensations as being equivalent to a mixture consisting of three primary colors [*Lorentz*, 1907]. On the basis of that, he claimed that a change in color can be detected if the intensity of one of the primary colors is changed by one hundredth. Objections to this view by contemporaries who challenged Doppler will be mentioned later.

Doppler's Life and Career

Christian Doppler's grandfather was a master stonemason. In 1791 he moved from Himmelreich, Bavaria, to Salzburg, No. 1, Makart Square. A year later, Doppler's father took over his grandfather's business. Christian was born in his grandfather's house on November 29, 1803. As the second son he was expected to become a stonemason like his father. Because of weak health he stayed longer in elementary school and had to repeat classes. He then transferred to Linz, where he attended the fourth class of high school and was about to enter his father's business, but his uncle and Professor Simon Stampfer both recognized Doppler's superior talent and recommended that he be allowed to further his education. His father agreed, and in October 1822, Doppler went to Vienna, where he took courses in mathematics, physics, and mechanics at the Polytechnic Institute. He remained there until January 1825 and distinguished himself through "diligence and outstanding behavior."

Although 22 years old, Doppler still had to complete his high school studies to gain admission to the university. In Salzburg he was privately tutored; he completed a 6-year course in 2½ years and classes in philosophy (grades 11 and 12) in 2 years. Meanwhile, he tutored others in mathematics and physics, supported his mother and sisters, studied French, Italian, and English, and learned accounting in a trade shop. In 1829 he returned to Vienna, where for 4 years he held the position of assistant to Hamschl in advanced mathematics at the Polytechnic Institute. During the years 1829–1833 he published papers in mathematics and physics, including "On the Theory of Parallels," "Convergence of an Infinite Logarithm Sequence," and "Likely Cause of Electrical Stimulation Through Friction." He decided to devote himself fully to a career in science. In September 1833, Doppler left the Polytechnic Institute and applied for teaching positions for which he had to pass special examinations. He was not successful.

His bitterness made him decide to emigrate to America. He went to Munich to contact the American Consul. At the same time he received several job offers. One was a professorship in mathematics and accounting at the City High School in Prague; another was to teach higher mathematics and physics at a high school in Bern. For patriotic reasons he accepted the former offer and in 1835 moved to Prague. The following year he married Mathilde Sturm, the daughter of a goldsmith and silversmith master from Salzburg. He was active at the City High School for 2 years, then became a substitute professor, and in 1841 a full professor at the Technical Institute in Prague. In the proceedings of the Royal Bohemian Society of the Sciences (which he had joined in 1840) he published several articles, including one on the colored light of double stars. In 1847 Doppler became a Professor of Mathematics and Physics in Schemnitz (Banská Štiavnica). During his short stay there he received an honorary doctor's degree in philosophy from Prague, and the Royal Academy of Sciences in Vienna awarded him full membership. The following year, in October 1848, he became a professor at the Polytechnic Institute in Vienna and succeeded his former teacher Stampfer to the chair in practical geometry. In 1850 the University of Vienna was authorized to establish a physics department, where the main purpose was to train high school physics teachers. Doppler became the head of this department with the rank of "ordinary" professor and served on the science examination commission for physics teachers. At age 47 he had achieved a highly honored position. However, his teaching load and the technical efforts weakened his body, but not his mind. He developed a lung disease. In autumn 1852 he requested sick leave and, following the advice of his doctor, went to Venice to recover. Sadly, on March 17, 1853, he died in his wife's arms, leaving behind five young children. He lies buried in the Venice cemetery, where a monument was erected in his honor.

Doppler's papers were published in various scientific journals: *Vienna Polytechnical Volumes*, *Hesler's Encyclopedic Magazine*, *Baumgartner's Magazine for Physics and Mathematics*, *Poggendorff's Annals of Physics*, *Proceedings of the Royal Bohemian Society of Sciences*, and the *Records of the Imperial Academy of Sciences of Vienna* [*Kunz*, 1904].

Because of the fast growth in science, many of Doppler's treatises have lost their significance. Only his principle of the Doppler effect achieved importance, and it continues to do so.

The Principle

The Doppler effect is a change in perceived frequency caused by motion of either the source or the observer. In other words, the Doppler effect is the change in the apparent time interval between two events caused, e.g., by the motion of the observer being added to the finite velocity of transmission of information about these two events [*Gill*, 1965]. Doppler stated his principle in 1842, first for sound and then for light. He applied his principle to the perceived colors of stars along their line-of-sight velocities. In his description of the effect for light, Doppler referred to the original vibration hypothesis of Huygens, according to which "the perception of color is an immediate consequence of the time intervals between regular, successive, and recurrent pulsations or wave crests of the ether. Therefore, anything that changes the time interval between pulsations must necessarily be associated with a change in perceived color." Doppler found it noteworthy that in the study of light and sound, and in wave theory in general, not enough attention had been paid to the subjective conditions (as opposed to objective conditions) that really determined the color and intensity of a light sensation or the pitch and intensity of sound. As long as the source of waves and the observer remained stationary at their original locations, it was clear that the subjective and objective determinations of color (light) or pitch (sound) coincided. This would not continue to be so, however, if either the source or the observer or both move toward or away from each other. Doppler expressed this as follows: "Assume that either the observer or the source or both simultaneously change their location, receding from or approaching each other, with a speed which is somewhat comparable to that of the wave. There is no doubt that the path length and the time interval between two successive wave crests shortens for an observer that moves against the wave motion, and becomes longer if he moves with the wave motion."

Doppler derived two simple equations describing the change of the time intervals depending on whether the source moves and the observer is stationary, or whether the observer moves and the source is stationary. Doppler's formula, restated in a simplified form [*Andrade*, 1959], is

$$f' = f[(c \pm u)/(c \mp v)] \qquad (1)$$

where f is the frequency of the source, f' is the frequency perceived by the observer, and c, u, and v are the velocity of the wave in a stationary medium and the velocities of observer and source with respect to this medium, respectively.

If one assumes that the speed of the source $v = 0$, one obtains for the perceived frequency of sound

$$f' = f[(c \pm u)/c] = f(1 \pm (u/c)) \qquad (2)$$

In the limit $u = c$, $f' = 0$ for the receding observer. For the approaching observer, $f' = 2f$. In the former case, sound waves do not reach the observer, and the sound is not perceptible. In the latter case, the pitch moves up by an octave.

If one assumes that the observer is stationary (i.e., $u = 0$), one obtains

$$f' = f[c/(c \mp v)] \qquad (3)$$

Article (*cont. on p. 1194*)

TABLE 1. Historical Summary: From the "Instantaneous" Propagation of Light to a Finite Speed of Light: From Discovery to Some Applications of the Doppler Effect

Date of Research	Research	Researcher	Date of Researcher
	Believed speed of light is finite	Empedocles	492–432 B.C.
	Believed light propagates "instantaneously"	Aristotle	384–322 B.C.
	Light propagates "instantaneously"; with proof!	Heron of Alexandria	?– 62 A.D.
	Felt more than he believed finite velocity of light	F. Bacon	1561–1626
1609	Designed first successful astronomical telescope; proposed experiments to determine speed of light	G. Galilei	1564–1642
	Believed light propagates "instantaneously"	J. Kepler	1571–1630
1621	Discovery of law of refraction	W. Snell	1591–1626
	Believed light propagates "instantaneously"	R. Descartes	1596–1650
1650	First discovery of a double star	G. Riccioli	1598–1671
1676	Discovery/determination of finite speed of light	O. Roemer	1644–1710
1678	Light is a longitudinal wave phenomenon	C. Huygens	1629–1695
1704	Associated specific wavelengths with each of several colors	I. Newton	1642–1727
1727	Discovery of aberration phenomenon	J. Bradley	1692–1762
1814	Discovery of absorption lines in solar spectrum	J. Fraunhofer	1787–1826
1817	Light is a transverse wave phenomenon	T. Young	1773–1829
1818	Huygens secondary wavelets combined with Young's idea of interference	A. J. Fresnel	1788–1827
1842	Discovery of Doppler principle: associated with longitudinal theory of light	C. Doppler	1803–1853
1844	Believed to have observed color changes in double stars; supported Doppler's idea that color of stars changes due to relative motion	B. Sestini	1816–1890
1844	Doppler principle valid for transverse theory of light	B. Bolzano	1781–1848
1845	Doppler principle verified in acoustics	C. H. D. Buys-Ballot	1817–1890
1848	Doppler effect applies to spectral lines but not to color	A. H. Fizeau	1819–1896
1852	Negation of Doppler's principle	J. Petzval	1807–1891
1859	Discovery of spectroscopic technique	R. Kirchhoff	1824–1887
		R. Bunsen	1811–1899
1860/1862	Resolution of Petzval-Doppler controversy	E. Mach	1838–1916
1863	First application of Doppler principle to astronomy	P. A. Secchi	1818–1878
1864	Unification of light and electricity	J. C. Maxwell	1831–1879
1868	Detection of red-shifted H-line (earth recedes from Sirius with 47 km/s)	W. Huggins	1824–1910
1871	Doppler-shifted spectral lines measured at limbs of sun	H. C. Vogel	1841–1907
1881	Interferometer experiment for speed of light and ether	A. A. Michelson	1852–1931
1887	Repeat of speed-of-light experiment	A. A. Michelson	1852–1931
		E. W. Morley	1838–1923
1889	Discovery that Mizar in Ursae Majoris is a spectroscopic binary star	E. C. Pickering	1846–1919
1889	Determination of orbital velocity of Venus	H. C. Vogel	1841–1907
1889	Existence of electromagnetic waves verified	H. Hertz	1857–1894
1895	First demonstration of the reception of electromagnetic signals	A. S. Popov	1859–1906
1900	Doppler principle for light verified in the laboratory	A. Belopolsky	1854–1934
1901	First transatlantic radio signal	G. Marconi	1874–1937
1904	Developed transformations that made Maxwell's equation invariant to all uniformly moving inertial frames	H. A. Lorentz	1853–1928
1905	Doppler principle tested in the laboratory on canal rays observing Hydrogen Palmer-line broadening	J. Stark	1874–1957
1905	Formulation of special theory of relativity	A. Einstein	1879–1955
1919	Discovery of recession of galaxies	E. P. Hubble	1889–1953
1925	First radio echoes from ionosphere using continuous wave techniques	E. V. Appleton	1892–1965
		M. Barnett	
1926	First radio echoes from ionosphere using pulse method	G. Breit	1899–1981
		M. A. Tuve	1901–1982
1940	Determination of meteor speed with radio Doppler method	D. D. Cherry	
		C. S. Shyman	
1950	Studies of upper atmosphere winds by radio echoes from meteor ionization trails	L. A. Manning	1923–
		O. G. Villard	1916–
		A. M. Peterson	1922–
Oct. 4, 1957	Doppler tracking of radio signals from Sputnik begins		

Article (cont. from p. 1193)

where v is the speed of the source. In the limit $v = c$, $f' = f/2$ if the source is receding, and $f' = \infty$ if the source is approaching. Here, for the receding source the pitch of a tone moves down by an octave, while for an approaching source all wave crests arrive at the observer at the same time, producing a sound of infinite pitch which cannot be heard.

At the conclusion of his 1843 paper, Doppler acknowledged that "Olaf Roemer taught us a value for the velocity of light," and that many years thereafter it was a general opinion that "no bodily motion in the heavens could compare in magnitude with that of light." He also stated that "there was Bradley who gave us the aberration phenomenon." Doppler went on to say that "if the orbital speed of the earth (4.7 mi/s with 1 mi = 6.38 km) produces an aberration of 20 seconds of arc, why should not a much larger speed cause a change in color and intensity of light." In fact, Doppler does not speak of "a possibility of such large speeds but rather of a necessity."

The verification of Doppler's principle for sound followed soon thereafter when *Buys-Ballot* [1845] placed musicians with excellent pitch perception along the railroad tracks between Utrecht and Maarsen. They estimated for approaches and recessions the pitch of the tone which a horn player produced onboard a moving train. The speed of the train was determined with two chronometers and a marked 100-m distance along the track. Among the astronomers of his time, only Benedetto Sestini from the Collegio Romano believed in Doppler's ideas on the color of stars. Sestini claimed that he had noted color changes in binary stars.

The laboratory demonstration of Doppler's effect for light was, of course, much more difficult than for sound, but it was carried out in the year 1900 by *Belopolsky* [1901]. In the following year, *Michelson* [1901], without calling Doppler's principle in question, suggested that the change in perceived frequency may be caused not only by motion of the source or the observer but also by a rapid alteration in the density of the medium crossed by the light ray.

Controversies

Color of Stars

Two controversies evolved around Doppler's work, which was challenged by Buys-Ballot and Petzval. Although Buys-Ballot had verified Doppler's principle for sound, he rejected the application of the principle to explain the color of binary stars on the following grounds:

1. The human eye does not have the sensitivity to color that Doppler believes.
2. A change in color due to the motion of a star cannot occur because should a part of the red spectrum disappear, ultraviolet reserves would appear; similarly, should a part of the violet spectrum disappear, ultrared reserves would appear.
3. Known velocities of celestial bodies were about 2×10^{-4} of the velocity of light, too small for the eye to perceive color changes resulting from motion.

Nevertheless, 7 years later, in 1852, Doppler, not accepting Buys-Ballot's critique of his change-of-color hypothesis, reaffirmed his conviction that the color of stars would be an aid for determining the trajectories of celestial bodies. This conviction was based on his seemingly unchangeable belief that the spectrum is a band of frequencies terminating at the red and violet, so that a receding motion of the source would shift the violet to the blue where the observed spectrum would end [*Andrade*, 1959]. It is interesting to note that the expansion of the universe, when deduced from observations of increasingly remote celestial objects, can give rise to color changes which Doppler originally anticipated for his stars [*Gill*, 1965; *Andrade*, 1959]. In spite of this development, Buys-Ballot's objections, which Doppler refuted [*Doppler*, 1846], were correct.

Doppler tied his principle to the longitudinal theory of light waves, assuming an ether, as Huygens did, but with the difference that the ether's individual particles are much finer than those of matter and could not be weighed. Although the transverse theory of light waves had been formulated by Young [*Stone*, 1963] in 1817, Doppler, while acknowledging in 1842 its success, remarked [*Doppler*, 1843] "that to believe this theory requires a lot of faith." Later, however, Doppler started wondering about whether his principle would be compatible with the transverse theory of light waves [*Lorentz*, 1907]. His doubts were dispelled by the Weltpriester Bolzano [*Haas*, 1904].

Petzval's Challenge

The validity of the Doppler principle was not universally accepted by men of science, the chief antagonist being Petzval. Petzval was born on January 6, 1807, in Szepes Bela, Hungary, the son of an elementary school teacher. At age 30 he became professor of mathematics and mechanics at the University of Vienna. He made significant contributions to the development of optical lenses for telescopes, microscopes, and binoculars. At one time he was assigned 10 military gunners to help with computations. The entire British Navy was eventually supplied with his binoculars. When thieves stole a large manuscript on optics from his apartment, he retreated to an abandoned monastery. From this domicile he rode daily on an Arabian horse to the university to give his lectures. Petzval died in Vienna, an almost forgotten man, on September 17, 1891.

It was shown earlier that according to Doppler, "the received frequency reaches infinity if the observer is at rest and the source moves with the wave speed in the medium." If the source moves faster than the wave speed, the received frequency would be negative. That cannot be, since the medium would be dragged along by the moving source and waves would form in the direction of motion such that the received frequency would have a finite, positive value.

Doppler made the error in believing that his elementary formulas were not approximations but would predict the exact magnitude of the frequency change. He ignored the effect that a moving body has on the state of a physical medium, omitted the medium from his formulas, and considered his equations as representing not only the pure principle but also the physical event. This gave *Petzval* [1852] the opportunity to prove Doppler's formulas to be in error relative to the physical event. Petzval went farther, however, and extended his criticism to the principle itself [*Gassauer*, 1950].

What was Petzval's argument, which surfaced about 10 years after Doppler's presentation in 1842? How was it resolved? Let us first state Petzval's law: If a source is located in a medium and all particles constituting the medium have identical velocity vectors and the required continuity condition of the flow is satisfied for all points at rest with respect to the source, then the received frequency equals the transmitted frequency irrespective of the physical properties and state of motion of the medium [*Gassauer*, 1950]. While Doppler acknowledged and appreciated the value of Petzval's law, he rejected the claim for its broad applicability. Petzval, in turn, rejected Doppler's principle. He also rejected popular views as providing no cognitive values for scientific understanding and claimed that to discover a principle of nature, one must start from differential equations.

The dispute was resolved conclusively in a series of articles published by *Mach* [1860, 1861, 1862]. Mach showed that Petzval's rule was valid only when source and observer are at rest with respect to each other. Doppler's principle, on the other hand, applied to any relative motion between source and observer, with Petzval's rule being only the special case when that motion is zero.

Modern Applications

Wide applications of the Doppler effect to fields other than astronomy have emerged only since World War II. Pulses of sound are backscattered from turbulence in the air by using a doppler acoustic sounder. The frequency of the radar echo shifts with the speed and direction of the wind. The wind is made "visible" by converting the numerical data into colors. This system has been used at factories to monitor the dispersal of pollutants and at airports to test wake turbulence and wind shear [*Ruby*, 1983]. Satellite measurements of atmospheric winds were made by using Bragg scattering of microwaves from centimeter-long surface ocean waves with amplitudes that vary with the wind speed just above the ocean surface [*Hibbs and Wilson*, 1983]. Doppler radar observation techniques are now revealing how a tornado is spawned by a thunderstorm [*Snow*, 1984]. The Mössbauer effect [*Stone*, 1963] was used to determine the apparent weight of a photon by allowing gamma rays to fall under gravity [*Pound and Rebka*, 1960]. Doppler speeds of the order of 10^{-3} cm/s between an emitter and absorber of gamma rays were used to reduce resonance absorption while searching for least counts of unabsorbed rays to obtain the wanted quantity.

The Doppler effect is also important in the study of wavelike perturbations in the ionosphere by means of high-frequency transmissions [*Toman*, 1976]. As the height of ionospheric layers is constantly changing, the propagation (phase) paths vary with time causing frequency shifts. This is illustrated in Figure 1. Over a 24-hour period, signal amplitudes and Doppler frequency variations at two operating frequencies originating from the time station CHU in Ottawa, Canada, were simultaneously received and recorded at a field site in Bedford, Mass., separated from the transmitter by a surface distance of 480 km. Time is read from right to left. The upper record illustrates the signal behavior for a carrier frequency of 7.335 MHz, the lower for 3.33 MHz. In each record the signal amplitude trace in microvolts is shown at the top, while Doppler shift traces associated with time variations of ionospheric phase paths are shown at the bottom. Vertical lines mark the hour, and horizontal lines identify the 0.5-Hz Doppler frequency interval. For 7.335 MHz, a 0.55-Hz Doppler shift corresponds to a speed of 20.4 m/s; for 3.33 MHz, a 0.5-Hz shift corresponds to 45.04 m/s. A relatively stable frequency trace is present for the 3.33-MHz carrier between 0800 and 1600 EST; at about 1630 EST a solar flare effect is identifiable by its doppler signature.

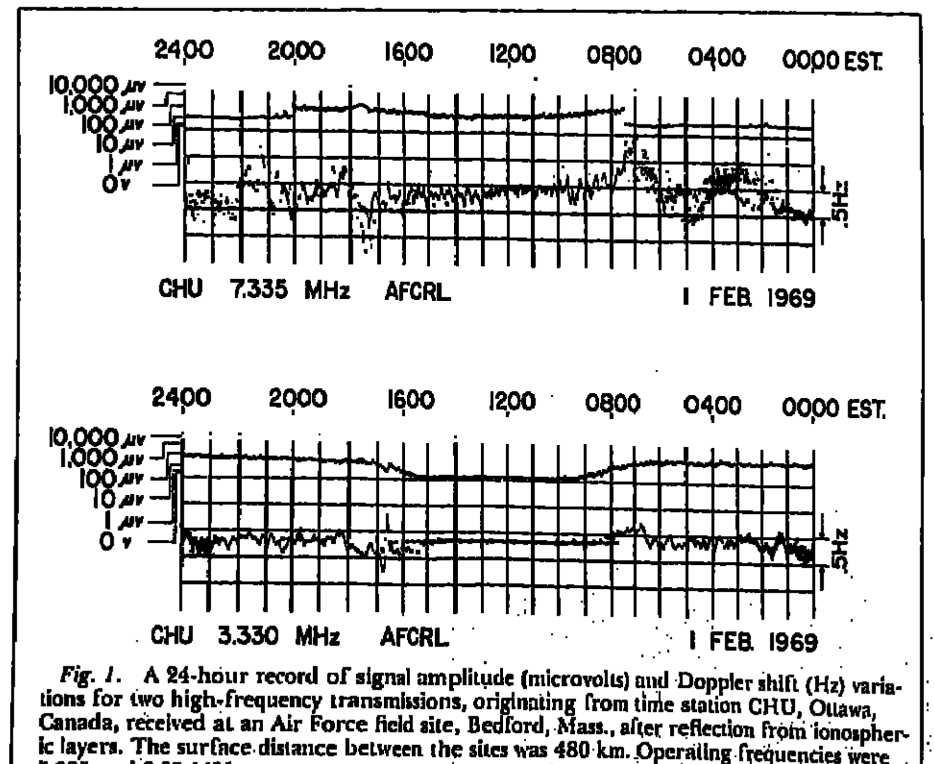


Fig. 1. A 24-hour record of signal amplitude (microvolts) and Doppler shift (Hz) variations for two high-frequency transmissions, originating from time station CHU, Ottawa, Canada, received at an Air Force field site, Bedford, Mass., after reflection from ionospheric layers. The surface distance between the sites was 480 km. Operating frequencies were 7.335 and 3.33 MHz.

Conclusion

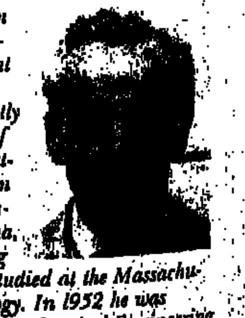
While Doppler's principle had a controversial beginning, the applications to astronomy, radio science, geophysics, navigation, communication, radar detection, meteorology, physics, etc., are impressive and growing. Doppler was the first to postulate changes in perceived frequency due to relative motion between source and observer. Consequently, his contribution links the early findings of Roemer and Bradley with those of Lorentz and Einstein.

Acknowledgment

This paper was presented at the National Radio Science Meeting, University of Colorado, Boulder, Colo., January 11–14, 1984.

References

Andrade, E. N. da C., Doppler and the Doppler effect, *Endeavour, 18*, 14–19, 1959.
Belopolsky, A., On an apparatus for the laboratory demonstration of the Doppler-Fizeau principle, *Astrophys. J., 13*, 15–23, 1901.
Bradley, J., and E. Halley, Account of a new discovered motion of the fixt stars, *Phil. Trans. R. Soc. London, 35*, 637–660, 1728.
Buys-Ballot, C. H. D., Akustische Versuche auf der Niederlandischen Eisenbahn, nebst gelegentlichen Bemerkungen zur Theorie des Hrn. Prof. Doppler, *Ann. Phys. 66*, 321–351, 1845.
Cohen, I. B., Roemer and the first determination of the velocity of light (1676), *Isis, 31*, 327–379, 1939.
Doppler, C., Über das farbige Licht der Doppelsterne und einiger anderer Gestirne des Himmels, Abhandlungen der königlich böhmischen Gesellschaft der Wissenschaften, 5; *Folge, 2*, 465–482, 1843.
Doppler, C., Bemerkungen zu meiner Theorie des farbigen Lichtes der Doppelsterne etc. mit vorzüglicher Rucksicht auf die von Herrn Dr. Ballot zu Utrecht dagegen erhobenen Bedenken, *Ann. Phys. Chem., 68*, 1–35, 1846.
Gassauer, T., Die wissenschaftliche Kontroverse zwischen Petzval und Doppler, Ph.D. Thesis, Univ. of Vienna, Vienna, Austria, 1950.
Gill, T. P., *The Doppler Effect: An Introduction to the Theory of the Effect*, Academic, New York, 1965.
Haas, K., Christian Doppler und seine Entdeckungen, *Vierteljahresbericht Wiener Vereines zur Forderung Phys. Chemischen Unterrichtes, 9*, 9–22, 1904.
Hibbs, A. R., and W. S. Wilson, Satellites map the oceans, *IEEE Spectrum, 20*, 46–53, 1983.
Kunz, E., Christian Doppler-Zur Feier seines hundertsten Geburtstages, Separat-Abdruck aus dem im Selbstverlage der Gesellschaft fur Salzburger Landeskunde erschienenen Mitteilungen, *44*, Salzburg, Austria, 1904.
Lorentz, H. A., *Abhandlungen von Christian Doppler*, Verlag von W. Engelmann, Leipzig, 1907.
Mach, E., Uber die Anderung des Tones und der Farbe durch Bewegung, Sitzungsberichte der kaiserlichen Akademie der Wissenschaften, *Math.-Naturwissen. Klasse, Vienna, 41*, 543–560, 1860.
Mach, E., Uber die Kontroverse zwischen Doppler und Petzval, bezuglich der Anderung des Tones und der Farbe durch Bewegung, *Zeit. Math. Phys., 6*, 120–126, 1861.
Mach, E., Uber die Anderung von Ton und Farbe durch Bewegung, *Ann. Phys., 116*, 333–338, 1862.
Michelson, W., On Doppler's principle, *Astrophys. J., 13*, 192–198, 1901.
Petzval, J., Uber ein allgemeines Prinzip der Undulationslehre: Gesetz der Erhaltung der Schwingungsdauer, *Sitzungsberichte K.K. Akad. Wissenschaften Wien, 8*, 134–156, 1852.
Pound, R. V., and G. A. Rebka, Jr., Apparent weight of photons, *Phys. Rev. Lett., 4*, 337–341, 1960.
Ruby, D., Visible wind, *Popular Sci. Mag.*, Nov. 1983.
Snow, J. T., The tornado, *Sci. Am., 250*, 86–96, 1984.
Stone, J. M., *Radiation and Optics*, McGraw-Hill, New York, 1963.
Toman, K., On wavelike perturbations in the F region, *Radio Sci., 11*, 107–119, 1976.



Kurt Toman has been with the Rome Air Development Center (RADC) at Hanscom Air Force Base since 1976. He is currently engaged in the analysis of Doppler-shifted radar clutter. He graduated with an MS degree from the Technical University of Vienna, Austria, in 1949. During the summer of 1949, he studied at the Massachusetts Institute of Technology. In 1952 he was awarded a Ph.D. degree in Electrical Engineering from the University of Illinois. For the next 3 years he was a postdoctoral research fellow at Harvard University, studying ionospheric motion. From 1955 to 1976 he was with the Air Force Cambridge Research Laboratories as project scientist, branch chief, and senior scientist in ionospheric physics.

News

NOAA Satellite Set For Launch

The latest in a series of National Oceanic and Atmospheric Administration (NOAA) meteorological satellites is scheduled for launch from Vandenberg Air Force Base, Calif., on December 1, 1984. High surface winds delayed the launch from the originally scheduled date of November 8. The 1712-kg satellite, the NOAA-F, is to be launched to an altitude of approximately 870 km into a circular near-polar orbit. The satellite is the sixth in the current series of 11 NOAA satellites that collect meteorological readings and transmit the data to ground stations for local weather analysis and forecasting.

The satellite, built by RCA Astro-Electronics, is an advanced TIROS-N (Television and Infrared Observation Satellite) and was built at a cost of $43.5 million. In addition to equipment for the collection of meteorological data, the spacecraft carries instrumentation that will allow it to pick up emergency transmission signals of downed aircraft and marine vessels in distress to help rescuers locate them. The instrumentation is part of a four-nation program involving the United States, the Soviet Union, Canada, and France.

NOAA-F, which will be called NOAA-9 once in orbit, carries an earth radiation budget experiment that will work in conjunction with the Earth Radiation Budget Satellite (ERBS) that was deployed from the space shuttle in October 1984. Other instruments carried on board the spacecraft include an advanced very high resolution radiometer (AVHRR) designed to monitor surface temperatures, cloud cover, and vegetation; a solar backscatter ultraviolet spectral radiometer (SBUV/2), which will make measurements of the total ozone concentration in the atmosphere and of the vertical distribution of atmospheric ozone; and an ARGOS/data collection system (DCS). The ARGOS/DCS will receive data from some 400 platforms—including buoys, free-floating balloons, and remote weather stations—that measure temperature, pressure, and altitude. NOAA-G, the next satellite in the series, is scheduled for launch no earlier than August 1985.

Scientific Instrumentation

The National Science Foundation (NSF), through its College Science Instrumentation Program (CSIP), is now accepting proposals from qualified undergraduate colleges or consortiums for the purchase of laboratory and instructional equipment. CSIP provides matching support from $5,000 to $50,000 for acquisition of new state-of-the-art instructional or scientific equipment or renovation, replacement, and upgrading of existing equipment. The deadline for submission of proposals is January 11, 1985. All fields of science and engineering are eligible for the grants.

Proposals will be evaluated on the basis of performance competence, intrinsic merit, utility, or relevance of the project, and effect on the infrastructure of science and engineering. Evaluation and processing of proposals will require approximately 6 months. Awards will be announced by June 1985. For further information, contact College Science Instrumentation Program, Directorate for Science and Engineering Education, National Science Foundation, Washington, DC 20550.

NSB Nominations

President Reagan has nominated three members to the National Science Board (NSB), the governing body of the National Science Foundation (NSF). None have been confirmed by Congress. They are Simon Ramo, director of TRW, Inc.; Annelise G. Anderson, a senior research fellow at the Hoover Institution, Stanford University; and K. June Lindstedt-Siva, manager for environmental sciences at Atlantic Richfield Company and a director of the Federal Home Loan Bank of San Francisco. Rita R. Colwell, vice president for academic affairs and professor of microbiology at the University of Maryland, is the newest NSB member. Five vacancies remain on the board.

Comet Quest

To begin the celebration of the return of Comet Halley, the Smithsonian Institution's National Air and Space Museum in Washington, D. C., has created a new planetarium show called "Comet Quest." The show explores the recorded history of comets, first studied 24 centuries ago in ancient China, and highlights what has become known as Halley's Comet, which will become visible in late 1985.

Geophysicists

Muawia Barazangi, a senior research associate at Cornell University and a specialist in seismology, has been appointed an adjunct professor and member of the graduate faculty in Cornell's Department of Geological Sciences.

Jerry D. Mahlman has been appointed director of the National Oceanic and Atmospheric Administration (NOAA) Geophysical Fluid Dynamics Laboratory in Princeton, N.J. Mahlman has been with NOAA since 1970.

Rosalind B. Mendell of New York University and ***Josephine T. Yingst*** of Wayne State University were among 29 female scientists to receive awards under the National Science Foundation (NSF) Visiting Professorships for Women program. Total amount for all 29 awards was $2.09 million.

William Jason Morgan of Princeton University has been granted the New York Academy of Sciences Award in the Physical and Mathematical Sciences. The presentation of the award will be made at the academy's annual meeting in New York City in December.

Several staff changes at NSF were announced recently. ***Garrett Brass***, of the University of Miami, has been appointed Program Director, Ocean Drilling Program, Division of Ocean Sciences. He succeeds ***Herman Zimmerman***. ***Richard B. Lambert, Jr.*** has been appointed Associate Program Director, Ocean Dynamics Program, also in the Division of Ocean Sciences. ***Clifford A. Jacobs*** has been appointed Centers and Facilities Manager, Division of Atmospheric Sciences. He succeeds ***Lawrence A. Lee***.

EOS

Transactions, American Geophysical Union

The Weekly Newspaper of Geophysics

For speediest treatment of contributions, send three copies of the double-spaced manuscript to one of the editors named below and one copy to AGU.

Editor-in-Chief: A. F. Spilhaus, Jr.; **Editors:** Marcel Ackerman, Mary P. Anderson, David A. Brooks, Bruce Doe, C. Stewart Gillmor (History), Clyde C. Goad, Louis J. Lanzerotti, Robert A. Phinney; **Managing Editor:** Barbara T. Richman; **News Writer:** David W. Robb; **Copy Editor/Writer:** Ruth Sochard; **Editorial Assistant:** Carol M. Ezzell; **Production Staff:** Celia Kate Burkhalter, Dae Sung Kim, Lisa Lichtenstein, Steven Mansberg, Kathryn M. Patton.

Officers of the Union

Charles L. Drake, President; Peter S. Eagleson, President-Elect; Peter M. Bell, General Secretary; Juan G. Roederer, Foreign Secretary; James A. Van Allen, Past President; A. F. Spilhaus, Jr., Executive Director; Waldo E. Smith, Executive Director Emeritus.

For advertising information, contact Robin E. Little, advertising coordinator, at 202-462-6903 or toll free at 800-424-2488. Advertising must be informative and consistent with the scientific and educational goals of AGU and is subject to approval by AGU. Advertisers and their agents assume liability for all content of their advertisements and for any claims arising therefrom against the publisher. Offers in advertisements are subject to all laws and are void where prohibited.

Subscription price to members is included in annual dues ($20 per year). Information on institutional subscriptions is available on request. Second-class postage paid at Washington, D. C., and at additional mailing offices. *Eos, Transactions, American Geophysical Union* (ISSN 0096-3941) is published weekly by

American Geophysical Union
2000 Florida Avenue, N.W.
Washington, DC 20009

Cover. Several stacked lava channels found on the island of Tenerife in the Canary Archipelago. Each channel was formed by the chilling and solidification of lava at the base and margins of the flow, which created a channel floor flanked by lava levees. The interior of the lava flow remained molten and fluid enough to drain away, leaving the open channel. Successive flows occupied existing channels, with each flow building a new floor and lava levees atop the old ones. Each channel is approximately 2.5 m across between the lava levees. (Photograph courtesy of Kenneth E. Windom, Associate Professor, Department of Earth Sciences, Iowa State University, Ames, Iowa.)

Geophysical Events

This is a summary of *SEAN Bulletin, 9*(10), October 31, 1984, a publication of the Smithsonian Institution's Scientific Event Alert Network. The complete bulletin is available in the microfiche edition of *Eos* as a microfiche supplement or as a paper reprint. For the microfiche, order document E84-011 at $2.50 (U.S.) from AGU Fulfillment, 2000 Florida Avenue, N.W., Washington, DC 20009. For the paper reprint, order *SEAN Bulletin* (giving volume and issue numbers and issue date) through AGU Separates at the above address; the price is $3.50 for one copy of each issue number for those who do not have a deposit account, $2 for those who do; additional copies of each issue number are $1. Subscriptions to *SEAN Bulletin* are available from AGU Fulfillment at the above address; the price is $18 for 12 monthly issues mailed to a U.S. address, $28 if mailed elsewhere, and must be prepaid.

Volcanic Events

Etna (Italy): As lava production ends, earthquake swarm starts.

Krafla (Iceland): Satellites detect SO_2-rich plume from September eruption.

Erebus (Antarctica): Large pumiceous bombs; lava lake frozen and uplifted.

Bezymianny (Kamchatka, USSR): Ash cloud; pyroclastic flows; part of dome destroyed.

Mayon (Philippines): Eruptive activity declines, but rains generate lahars.

Bulusan (Philippines): Volcanic earthquakes and slight inflation.

Home Reef (Tonga): Ships steam through pumice SE of Fiji.

Rabaul (New Britain): Large earthquake swarm accompanied by rapid uplift.

Bagana (Solomon Islands): Lava flow continues; earthquake swarm.

Balbi (Solomon Islands): Boiling mud, active fumaroles, and solfataras.

Loloru (Solomon Islands): Solfataras active on dome and flank.

Aso (Japan): Block and ash ejection from fumarole.

Kaitoku Seamount (Izu Islands, Japan): Discolored water after 3 months of quiet.

Kilauea (Hawaii): Phase 26; shortest of 1983–1984 eruption.

Mount St. Helens (Washington): Deformation, seismicity, and gas emission low.

Ol Doinyo Lengai (Tanzania): Fumarolic activity.

Atmospheric Effects: Lidar data from Italy and Germany.

Bezymianny Volcano, *Kamchatka Peninsula, USSR (56.07°N, 160.72°E). The quoted material is a report from G. Ye. Bogoyavlenskaya and P. I. Tokarev.*

"Activity at Bezymianny increased from late September through mid-October. On September 4, small surface earthquakes began to be recorded at a seismic station 13 km from the volcano. By October 8, the number of recorded events was 300 per day. On October 9, ash ejections became frequent and rockslides occurred from the dome. On October 13–14, the eruption entered its main phase. Volcanic tremor began, and an eruption column rose to 5 km height. Several explosions destroyed the E portion of the summit dome. Pyroclastic flows descended along two routes, the larger more than 8 km long. Ashfall occurred to the ENE. The ash layer 16 km NE of the volcano was 2 kg per m². Weaker activity followed, and by October 19 the eruption was over."

No eruptions of Bezymianny were known for more than 250 years after the Russian discovery of Kamchatka in 1697. Ash eruptions began in 1955, followed by lava dome extrusion and intrusive activity, culminating in a paroxysmal directed explosion on March 30, 1956, that destroyed the summit and formed a large crater, elongate to the east. Lava extrusion resumed, punctuated by numerous explosive episodes, and has continued, building the Novy (new) dome (G. Ye. Bogoyavlenskaya and I. T. Kirsanov, 25 Years of Activity at Bezymianny, *Volcanol. Seismol., 2*, pp. 3–13, 1981). Bezymianny's last reported activity was an eruption May 22, 1983, without premonitory seismicity (see *SEAN Bulletin, 8*(5)). Strong explosions ejected ash to 5–6 km heights, part of the lava dome was destroyed, and a 4–5-km-long pyroclastic flow deposit was observed at the E foot of the dome.

Information Contacts: G. Ye. Bogoyavlenskaya and P. I. Tokarev, Institute of Volcanology, Piip Avenue 9, Petropavlovsk, Kamchatskii 683006 USSR.

Home Reef Volcano, *Tonga Islands, S Pacific (18.99°S, 174.78°W).*

While traveling southeast of Fiji in May, June, and July, Dutch ships encountered rafts of floating pumice, probably from the March eruption of Home Reef (see *SEAN Bulletin, 9*(2 and 4)).

On May 14 between 1200 and 1630 UT, the *m.v. Amanda Smits* traveled through floating pumice from 18.10°S, 178.90°E to 18.78°S, 178.17°E, about 675 and 740 km WNW of Home Reef. The pumice ranged in size "from grit to large dice."

A volunteer meteorological observer aboard the *m.v. Nedlloyd Alkmaar* reported that the vessel first encountered pumice on June 7 at 1900 UT at 21.58°S, 177.85°W (about 430 km SW of Home Reef). Steaming on a course of 282° (slightly N of W), the ship continued to pass through pumice rafts of varying density for nearly 280 km, with the last observation on June 8 at 0500 UT at 21.03°S, 179.53°E (about 635 km WSW of Home Reef). Pumice fragments ranged in size from "fine grit" to about 10 cm in diameter. Live shellfish up to 1 cm across that looked like mussels were attached to some pumice fragments.

The *m.v. Nedlloyd Barcelona* sailed through small amounts of pumice July 20–21; her positions July 20 at 1800 UT and July 21 at 0000 were 22.4°S, 178.7°E and 24.0°S, 178.7°E, about 775 and 875 km SW of Home Reef. Pumice fragments reached a maximum size of 2–3 cm and were aligned in E–W strands up to several hundred meters long.

Pumice was first reported in the vicinity of Fiji in April. By early May, large pumice rafts in several regions around Fiji forced ships to return to port and had covered the shorelines of many islands (see *SEAN Bulletin, 9*(7)). Pumice reached Futuna and Alofi Islands in April, Vanuatu by late June, the Loyalty Islands in August, and New Caledonia by early September (see *SEAN Bulletin, 9*(8 and 9)).

Information Contact: L. J. Mahieu, Head, Bureau of Marine Affairs, Division of Oceanographic Research, Royal Netherlands Meteorological Institute, Postbus 201, 3730 AE De Bilt, Netherlands.

Rabaul Caldera, *New Britain Island, Papua New Guinea (4.27°S, 152.20°E). All times are lo-*

News (cont. on p. 1196)

News (cont. from p. 1195)

cal (= UT + 8 hours). This report is from P. Lowenstein.

"Seismicity and rates of ground deformation reintensified at Rabaul Caldera in October. The total number of caldera earthquakes for the month was 6,749, and seismic energy released was 1.5×10^{19} ergs, as compared to 4,048 earthquakes and 9×10^{16} ergs of seismic energy released in September (see last month's *SEAN Bulletin*, *Eos*, October 23, 1984, pp. 771–772).

"The increased level of activity was due mainly to a seismic and ground deformation crisis on October 18. The seismicity was concentrated in the Blanche Bay area and included four moderate-to-strong earthquakes (M_L 4.9, 3.6, 3.35, and 3.3). The seismic energy released during the crisis amounted to 1.4×10^{19} ergs, about 90% of the month's total seismic energy. Tilt changes measured soon after the crisis indicated a deformation source immediately offshore (W) from Sulphur Point, at the N edge of Blanche Bay. The maximum measured tilt change was about 90 microradians. Using a point-source model, the deformation source was calculated to be about 1.2 km deep, and the volume change at the source about 1×10^6 m³. The uplift at Sulphur Point was about 100 mm. The ground deformation associated with the crisis was very localized. At the SE coast of Matupit Island, about 1.5 km from the deformation source, the uplift was only 33 mm; at the N shore of Greet Harbour, about 2.5 km away, it was only 5 mm. No marked horizontal deformation took place in association with the crisis.

"In addition to the crisis on October 18, there were a number of seismic swarms and a few moderate-to-strong discrete earthquakes. The most notable of these events were a swarm at Greet Harbour on October 8 (maximum M_L 3.8), a moderate-to-strong earthquake (M_L 3.8) at the entrance to Blanche Bay about 10 hours after the crisis on October 18, and seismic swarms from around the Vulcan headland on 24 (maximum M_L 2.8) and October 26 (maximum M_L 3.2).

"Most of the ground deformation in October took place on the 18th, but tilting and uplift continued at a reduced rate around Greet Harbour for the remainder of the month. An offset of about 25 microradians was registered at 1 station on Vulcan after the seismic swarm on October 26. The maximum amount of ground deformation recorded for the month was 130 microradians tilt and 100 mm of uplift at Sulphur Point. Horizontal deformation was mostly insignificant, although a distinct N-S dilation was evident at the mouth of Blanche Bay. This was due largely to a northward shift (about 50 mm) of Sulphur Point."

Information Contact: P. Lowenstein, Principal Government Volcanologist, Rabaul Volcano Observatory, P. O. Box 386, Rabaul, Papua New Guinea.

Earthquakes

Date	Time, UT	Magnitude	Latitude	Longitude	Depth of Focus	Region
Oct. 9	1154	4.0 m_{bLg}	34.72°N	85.16°W	5 km	NW Georgia
Oct. 18	0948	5.4 M_s	40.57°N	42.50°W	shallow	Senkaya, E Turkey
Oct. 18	1530	5.3 m_b	42.43°N	105.78°W	20 km	central Wyoming

Information Contracts: National Earthquake Information Service, U.S. Geological Survey, Stop 967, Denver Federal Center, Box 25046, Denver, CO 80225.

Meteoritic Events

SW Western Australia, September 30.

Fireballs

W Australia; S Pacific Ocean; S central Kansas, central Oklahoma, NW and central Oregon, Oregon-Washington, NE Texas, E Washington (2).

Books

AGU New Books

Groundwater Transport: Handbook of Mathematical Models

Groundwater Transport: Handbook of Mathematical Models
I. Javandel, C. Doughty, and C. F. Tsang, *Water Resour. Monogr. Ser.*, vol. 10, AGU, Washington, D. C., 1984, ISBN 0–87590–313–4. AGU members, $11.20; others, $16.00.

Enormous amounts of waste materials potentially hazardous to groundwater are stored or disposed of on or beneath the land surface. In many instances, contaminants, including both organic and inorganic chemicals and bacteriological substances, are found in groundwater, indicating that many of the waste disposal sites communicate with underground water resources.

Concerns over groundwater pollution have resulted in the passage of legislation during the last decade calling for pollution control and remedial measures to ensure proper drinking water quality. There are two main types of groundwater pollution caused by man: pollution caused by the use of pesticides, herbicides, and fertilizers over agricultural lands, where the source of contamination covers a relatively large area, and pollution caused by industries and municipalities, which is generally more localized. For the second type, because the contamination in the groundwater is localized, the design of any remedial measure requires knowledge of the extent of the contamination plume.

This book puts together a selection of various mathematical approaches and methodologies for estimating the extent of groundwater contamination. The strengths and possible pitfalls in application of each method are clearly discussed. The methods presented range from simple analytical and semianalytical solutions to complex numerical codes. Detailed discussions of the assumptions underlying application of the methods are given. Primary emphasis is on the use of simple formulas and comprehensive tables so that the book is practically oriented and readily useable as a guide in the field. Listings and user's guides for simple computer programs are given, which enable the reader to extend the tables.

Chapter 1 reviews major sources and types of common pollutants found in the groundwater. Some simple analytical methods based on the solution of applicable differential equations are discussed in Chapter 2. Application of these solutions is very simple and requires a minimal set of essential data. The use of several examples leads the reader step by step through the application of the material presented. The accuracy of the results depends upon the degree to which the data set used adequately represents the field characteristics. In many cases, where the amount of available data is limited, analytical methods are perhaps the best approach to the problem.

Semianalytical methods based on the concept of the complex velocity potential are discussed in Chapter 3. These techniques provide the streamlines for steady state fluid flow and the corresponding contaminant movement in the presence of an arbitrary number of sources and sinks. An average geological environment is assumed, and a schematic chemical retardation factor is considered. A listing of a powerful computer code, RESSQ, and its user's guide are provided. The use of several examples helps the reader to easily follow the approach and apply the computer code to trace the path of contaminants within the groundwater.

Chapter 4 refers to sophisticated numerical models currently being used for calculation of flow and transport of solutes. Key characteristics of different models and the persons involved in their development are introduced. These models can generally handle the complex geometry and boundary conditions typical of subsurface media. Anisotropy and heterogeneity of the media with respect to hydrological properties can be easily treated. Various transport processes, such as advection, dispersion, diffusion, adsorption, radioactive decay, and ion exchange, can be considered with some available codes. An example of the use of one such numerical model is included in this chapter. Finally, Chapter 5 discusses the kind of data needed by each method and then addresses the selection of the best method for handling a given problem.

The strong point of this book is its approach, which is designed to clearly present a selection of important and complex mathematical methods in a format readily usable by the readers. The book will be an effective means of technology transfer from the scientific community to those responsible for investigating a given groundwater contamination site and making necessary decisions for remedial action. Extensive tables, as well as listings and user's guides of simple computer programs which can be used with widely available personal computers, are included for this purpose.

Iraj Javandel *received his Ph.D. in Civil Engineering from the University of California, Berkeley, in 1968. After spending 1 year of postdoctoral study at Berkeley, he joined the Pahlavi University faculty in Shiraz, Iran, where he was the Chairman of the Civil Engineering Department and taught courses in hydraulics and groundwater. He also taught courses in flow in porous media at the University of California, Berkeley during 1973–1974. He has been a staff scientist in the Earth Sciences Division of the Lawrence Berkeley Laboratory since 1980. He was one of the pioneers in applying the finite element method to flow through porous media in 1967. His current principal interests are the hydraulics of wells, mathematical modeling of groundwater contamination, and underground injection.*

Christine Doughty *received a B.S. in Engineering Physics from the University of California, Berkeley in 1978 and is now a Staff Scientist in the Earth Sciences Division of the Lawrence Berkeley Laboratory. Her principal research interest is the mathematical modeling of underground fluid flows, such as contaminant transport in groundwater and hydrothermal flow in aquifer thermal energy storage systems and geothermal fields. Recent work includes studies in the characterization of aquifer thermal energy storage systems based on a dimensionless parameter approach and development of a thermal well test method for determination of aquifer hydraulic and thermal properties. Current research efforts involve extension and generalization of the semianalytical models for contaminant transport in groundwater that are discussed in this volume.*

Chin-Fu Tsang *received his Ph.D. in Physics from the University of California, Berkeley in 1969 and is currently a Senior Staff Scientist and the Deputy Group Leader of the Hydrogeology and Reservoir Engineering Group in the Earth Sciences Division of the Lawrence Berkeley Laboratory, Berkeley, Calif. His research interests range from advanced well test methods, flow of fluids through porous and fractured media, and nonisothermal reservoir dynamics to coupled thermomechanical hydrochemical processes in subsurface formations. He has carried out analytical and numerical modeling studies in reinjection into geothermal reservoirs, aquifer thermal energy storage, thermohydraulic phenomena around a nuclear waste geological respository, and contaminant transport in porous fractured media. He has been the editor of the* International Seasonal Thermal Energy Storage Quarterly Newsletter *for the last 6 years and was one of the editors for the* Journal of Environmental Geology *from 1980 to 1984. His recent interests are groundwater contamination studies and coupled thermomechanical hydrochemical processes affecting transport from a nuclear waste repository.*

Classified

RATES PER LINE

Positions Available, Services, Supplies, Courses, and Announcements: first insertion $5.00, additional insertions $4.25.
Positions Wanted: first insertion $2.00, additional insertions $1.50
Student Opportunities: first insertion free, additional insertions $2.00.

There are no discounts or commissions on classified ads. Any type style that is not publisher's choice is charged at general advertising rates. *Eos* is published weekly on Tuesday. Ads must be received in writing by Monday, 1 week prior to the date of publication.

Replies to ads with box numbers should be addressed to Box ___, American Geophysical Union, 2000 Florida Avenue, N.W., Washington, DC 20009.

For more information, call **202-462-6903 or toll free 800-424-2488.**

POSITIONS AVAILABLE

Massachusetts Institute of Technology: Haystack Observatory/VLBI Radio Astronomy. Haystack Observatory invites applications for a one year term appointment, renewable for a second year, for a recent Ph.D. recipient in radio interferometry. Applicants should have an enthusiastic interest in the study of extragalactic and galactic radio sources through VLBI.

Haystack is the site of the Mark III Correlator, and is in the process of adapting a minicomputer for application to imaging and post-processing of astronomical data, including an implementation of AIPS.

The successful candidate will be expected to carry out a research program both independently and in collaboration with Haystack VLBI staff, whose current research programs include millimeter-wavelength VLBI, both superluminal and stable compact sources, and radio stars. A significant fraction of the researcher's time will be devoted to support of Observatory activities, including processing and postprocessing of data from the Mark III Correlator or possibly to support of U.S. VLBI Network observations.

Please write, enclosing resume, to:
J.T. Karaku
Assistant to the Director
Haystack Observatory
Westford, MA 01886.

The University of Minnesota: Structural Geology/Tectonics. The University of Geology and Geophysics invites applications for a new, tenure track position in structural geology and tectonics. Candidates will be expected to carry out an active research program in their field of interest and to assume teaching and advising responsibilities at the undergraduate and graduate levels. A Ph.D. is required. The position will be available fall 1985. Application deadline is February 15, 1985. Applicants should send curriculum vitae, list of publications, statement of research interests, and names of at least three referees to Peter Hudleston, Chairman, Department of Geology and Geophysics, University of Minnesota, Minneapolis, Minnesota 55455.

The University of Minnesota is an equal opportunity educator and employer and specifically invites and encourages applications from women and minorities.

Faculty Position in Dynamical Oceanography.
An academic position (tnure track) is presently available at the assistant or junior associate professor level in the Department of Oceanography, Naval Postgraduate School. An ocean dynamicist experienced in the modeling of mesoscale ocean processes is preferred. The candidate shoudl be comptetent in the anlysis of pertinent observations, and be able to teach a variety of graduate courses in physical oceanography. The applicant should have an earned Ph.D. with an academic background in physical oceanography or a closely related field. Desirable attributes include field experimental interest and eexperience at sea and.or a strong interest in satelite remote sensing of the ocean. The successful candidate will be expected to each one or two quarters per years, conduct sponsored research, and provide thesis supervison. The access to computer, data archive, and research vessel facilities is excellent. Basic nd applied research opportunities are abundant. Interactions with ocean dynamicists in the Meteorology Department are also possible. Salaries are attractive and are determined by the qualifications of the successful candidate. By 1 January 1985, send a curriculum vitae, hte nmes oand addresses of three reforences, and a statement of research and instructional intersts to:
Professor Christopher N.K. Mooers, Chairman
Department of Oceanography
Naval Postgraduate School
Monterey, CA 93943.

Applicants who are currently doctoral canddidate will be considered for appointment as instructors, with a tenure track appointment upon completion of the degree. For additional information, telephone Professor Edward B. Thornton at 408-646-2847.

The Naval Postgraduate School is an equal opportunity/affirmative action employer.

Postdoctoral Fellowship/Coastal Marine Scholar. The Marine Sciences Research Center is seeking recent Ph.D.'s as candidates for a postdoctoral research position in any aspect of marine science, coastal zone management, or related disciplines. Two years of academic year stipend ($18,000 for 10 months) will be provided and scholars are encouraged to pursue their own research interests. Summer support should be available September 1, 1985. All requirements for Ph.D. must be completed by time of appointment. Submit resume, detailed statement of research interests and three letters of recommendation by February 15, 1985 to: Dr. J. Kirk Cochran, Marine Sciences Research Center, SUNY Stony Brook, Stony Brook, NY 11794-5000.

SUNY Stony Brook is an affirmative action/equal opportunity educator and employer. AK#289C-84.

Physical Oceanographer/North Carolina State University. Applications are invited for a nine-month, state funded, tenure track position at the assistant or associate professor level in descriptive physical oceanography. The successful applicant will have a Ph.D., a background in ocean circulation and state of the art instrumentation, and will be expected to develop a strong field program and teach graduate level courses. He or she will also have the opportunity of interacting with thirty-two departmental faculty in various areas in oceanography, meteorology and geology. Send curriculum vitae and the names of three references by January 31, 1985 to: Dr. G.S. Janowitz, Chairman, Search Committee in Physical Oceanography, Department of Marine, Earth and Atmospheric Sciences, Box 8208, Raleigh, NC 27695-8208, Telephone 919-737-3711.

North Carolina State University is an equal opportunity/affirmative action employer.

Massachusetts Institute of Technology: Haystack Observatory/Atmospheric Scientist. The Haystack Observatory is accepting applications for an anticipated Atmospheric Scientist position for a one-year period, equivalent to a postdoctoral appointment, to work in the field of upper atmospheric physics with the Millstone Hill Atmospheric Sciences group. The scientist will participate in the analysis of data from multi-technique experimental campaigns performed under the Global Thermospheric Mapping Study program being coordinated from Millstone Hill. The applicant should have some experience in an area of upper atmospheric science and familiarity with computers, magnetic tape formats, computer graphics and display techniques. New Ph.D. preferred. Please write, enclosing resume, to:
J.T. Karaku
Assistant to the Director
Haystack Observatory
Westford, MA 01886.

MIT is an equal opportunity/affirmative action employer.

Seismologist/Ohio State University. The Department of Geology and Mineralogy, The Ohio State University, invites applications for a tenure track position for a seismologist with research interests in crustal geology and tectonics. The successful applicant must be prepared to assist in teaching exploration geophysics courses, advanced topics in his/her specialty, conduct research, and supervise graduate students. Postdoctoral or industrial experience is desirable. Rank and salary commensurate with experience and research record. Please send applications or nominations to:
Dr. Ralph R.B. von Frese
Chairman, Search Committee
Department of Geology and Mineralogy
The Ohio State University
Columbus, OH 43210
Telephone: (614) 422-5635 or 422-7221.

Applications should include a resume, a statement of research interests and the names and addresses of at least three persons whom we may contact for recommendations. The closing date for applications is December 1, 1984; or until position is filled; appointment can be effective as soon as October 1, 1985. Additional information can be obtained by writing or calling the chairman of the search committee.

The Ohio State University is an equal opportunity/affirmative action employer.

Astronomy/Magnetospheric/Planetary/Digital Imaging Scientists. This is an opportunity to become involved in state-of-the-art data management issues, techniques, and solutions while simultaneously pursuing research interests. The National Space Science Data Center at the Goddard Space Flight Center is in an exciting transitional period and has three new openings on its contract staff for data oriented scientists in the above areas. These individuals will join with several others in attacking a broad range of activities, primarily intended to facilitate access to and utility of space science data in an evolving technological environment. These activities include development of an online data catalog, interfacing with Principal Investigators and spacecraft project offices for data accessibility and documentation, preparing data catalogs, generating techniques for coordinated multi-spacecraft data acquisition and analysis, and generation of composite or other value-added data sets. Research interests are encouraged and may be pursued on a substantial part-time basis. A Ph.D. is preferred, although a Master's degree will be considered for some activities. Experience with space flight experiments, data analysis techniques, data presentation, publications, and programming is highly desirable. Specific duties will depend upon an individuals background and interests. Send resume to: Linda Williamson
Sigma Data Services Corp., a M/A-COM Co.
Code 633
National Space Science Data Center
NASA/GSFC
Greenbelt, Md. 20771
(301) 344-8148

Sigma Data Services Corp., a M/A-COM Co. is an equal opportunity affirmative action employer.

President
Incorporated Research Institutions for Seismology

Chief Executive Officer sought for newly created non-profit scientific consortium. Responsible directly to Board of Directors. Will work closely with member institutions, deal with Government agencies, congressional committees and corporation. Will direct staff and oversee IRIS standing committees. Applicants must have Ph.D. in the physical sciences, experience in research administration and knowledge of operation of U.S. government agencies, congressional committees and high-level university administration. Submit curriculum vitae and names and addresses of three references to Box 028, American Geophysical Union, 2000 Florida Avenue, NW, Washington, D.C. 20009.

University of Utah: Structural Geology/Tectonics/Tectonophysics. The Department of Geology and Geophysics at the University of Utah seeks applications for a tenure track position in structural geology, tectonics or tectonophysics. It is anticipated that this position will be filled at the assistant professor level, but applications by more senior persons will be considered. The position requires a Ph.D. with emphasis in structural geology, regional tectonics or tectonophysics. The new faculty member will have the opportunity to teach in the area of his or her specialty and may also be assigned introductory level courses. The successful candidate will be expected to establish a vigorous research program involving graduate students. The person who fills this position will join an active program in structural geology and tectonics that includes both field projects and integrated geology/geophysics and mechanics/fluid chemistry studies of structures in the western Cordillera. There is an excellent opportunity to collaborate with other faculty in structural geology, sedimentology, geophysics, geochemistry and petrology. A vita, copies of publications, names of three persons that may provide references, and a letter outlining the candidate's research and teaching interests should be sent to: Dr. William P. Nash, Chairman, Department of Geology and Geophysics, University of Utah, Salt Lake City, Utah 84112–1183. Deadline for receipt of applications is December 31, 1984 with the appointment starting in September 1985.

The University of Utah is an equal opportunity/affirmative action employer.

Marine Geophysicist/Texas A&M University. The Department of Oceanography invites applicants for a tenure track position in its geological/geophysical section in the general field of marine geophysics and global tectonics. A Ph.D. is required. Rank and salary of the position are open. The successful applicant will be expected to initiate a vigorous research program, have an interest in seagoing activities, and interact with colleagues in the Departments of Oceanography, Geophysics, and the Geodynamics Research Program. Duties will also include the teaching of M.S. and Ph.D. students. The position is available beginning September 1, 1985. Applicants should submit a detailed resume including names of references and statement of research interests to T. K. Treadwell, Faculty Search Committee Chairman, Department of Oceanography, Texas A&M University, College Station, Texas 77843. Closing date for applications is January 31, 1985.

Texas A&M University is an equal opportunity/affirmative action employer.

Computer Manager/Minicomputer Specialist. Memphis State University seeks a candidate to manage a PDP 11/44 and a major facility expansion to include a superminicomputer system (VAX 11/785 class) to be dedicated to research applications in the Geological Sciences and Geophysics. Hardware and software are designed for digital seismic data acquisition, digital seismic data processing, and graphical representation of geological and geophysical data.

The candidate must have at least a BS degree in Computer Science, Electrical Engineering or related field; three years programming experience including FORTRAN and ASSEMBLY; knowledge of various computer hardware and two or more widely used operating systems; ability to perform numerical data analysis. Knowledge of PASCAL and C languages and RSX11M operation system will help.

Salary is negotiable depending on experience. Applicants should submit a resume, copies of academic transcripts, and the names, addresses and telephone numbers of three references to:
Dr. Jer-Ming Chiu
Memphis State University
Tennessee Earthquake Information Center
Memphis, TN 38152.

Applications must be received by December 10, 1984.

Memphis State University is an equal opportunity/affirmative action employer.

University of Illinois at Chicago. The Department of Geological Sciences seeks to fill tenure track positions probably, but not necessarily, at the rank of assistant professor, probably effective Fall, 1985, pending budgetary approval, in one or both of the following disciplines: 1) Geophysics (preferably in seismology); 2) sedimentary geochemistry. Each person is expected to teach both undergraduate and graduate courses and to conduct a vigorous research program, including the supervision of graduate students. PhD required. Applicants should submit a detailed resume, names and addresses of three references, and an explanatory statement of research and teaching interests by February 28, 1985, to Robert DeMar, Department of Geological Sciences, University of Illinois at Chicago, Chicago, Illinois 60680. Representation of the Department will be at the AGU Fall Meeting in December.

The University is an equal opportunity/affirmative action employer.

University of Wyoming/Department of Geology and Geophysics. The Department of Geology and Geophysics encourages applications from students interested in pursuing graduate research in the fields of igneous and metamorphic petrology and geochemistry. Current research topics, involving field and laboratory studies, include: island arc and continental volcanics, petrogenesis of granitic and anorthositic rocks, evolution of the Archean crust, petrogenesis of mylonitic rocks, and geothermometry and geobarometry as applied to the evolution of orogenic terranes. Facilities include: an analytical geochemical lab for whole-rock and trace element analysis, a fully automated CAMECA microprobe, two JOEL scanning electron microscopes, a thermal ionization mass spectrometer for analyzing Rb-Sr, Sm-Nd, and U-Th-Pb isotopes, a microthermometry lab, and an experimental petrology lab. Applicants should contact:
Petrology/Geochemistry Program
Department of Geology and Geophysics
PO Box 3006, University Station
University of Wyoming
Laramie, WY 82071.

Organic Chemical Oceanographer. The College of Marine Studies invites applications for a tenure track position in chemical oceanography. Applicants should have a background in organic chemical oceanography, experience in analysis of specific organic compounds, and field experience. Interest or experience in estuarine and coastal research is preferred. The successful applicant will have the opportunity to develop independent and cooperative research within existing interdisciplinary estuarine and coastal research programs. Facilities available include a modern research campus in Lewes, Delaware, and the 120-foot research vessel R.V. Cape Henlopen. Teaching at the graduate level will be required, and the successful candidate will be expected to develop a funded research program and advise MS and PhD students. It is anticipated that the position will be at the Assistant Professor level, but applications from more senior persons are welcome. Applicants should send curriculum vitae, pertinent reprints, and the names of three references to the Chairperson of the Search Committee: Dr. Jonathan H. Sharp, Oceanography Program, College of Marine Studies, UNIVERSITY OF DELAWARE, Lewes, DE 19958. Telephone: 302-645-4259. The closing date for applications is December 15, 1984.

The University of Delaware is an equal opportunity employer.

NATIONAL SCIENCE FOUNDATION (NSF)

Program Director
Instrumentation and Facilities Program

NSF's Division of Earth Sciences is seeking qualified applicants for the position of Program Director for its new Instrumentation and Facilities Program. The position is in the excepted service and will be filled on either a permanent, rotator or temporary basis. The per annum salary for the permanent or temporary position will be at GH-15 level, $50,495 to $65,642. Normally, the rotator candidate receives a leave of absence from his/her employer and salary is set in accordance with NSF's Circular 167, Rotator Program. The salary range for the rotator position is $40,000 to $66,400. The program provides support for the purchase and upgrading of research instrumentation and equipment for earth sciences research at universities and colleges in the U.S. Some support is also provided for the design and development of new research instrumentation for earth sciences, and for the operation of centralized research facilities used by several institutions.

Applicants should have a Ph.D. in the Earth Sciences or equivalent experience. In addition, six to eight years of successful scientific research experience in geochemistry and/or geophysics beyond the Ph.D. Demonstration of extensive research experience and productivity could be considered as equivalent to a Ph.D. A broad general knowledge of earth sciences research and research instrumentation as well as familiarity with the U.S. scientific community are also required. Administrative experience, preferably in a university or in government, is highly desirable. Applicants should send resumes indicating current salary to:

National Science Foundation,
Personnel Administration Branch,
1800 G St. NW,
Rm. 212, Washington, DC 20550
Attn: Catherine Handle

When applying for the permanent position indicate #EX 85-2 in the cover letter and #EX 85-1 when applying for the rotational position. For further information call 202/357-7840. Hearing impaired individuals should call 202/357-7492.

NSF is an Equal Opportunity Employer.

Anticipated Petrology/Mineralogy/Volcanology: Louisiana State University. The Department of Geology is searching for candidates to fill positions in metamorphic petrology, economic mineralogy, and volcanology associated with studies of pyroclastics, remote sensing of volcanic landforms, or geophysical interpretation of subsurface volcanic features. Successful applicants are expected to offer graduate and undergraduate courses in their specialties and to develop a strong record of funded research and publications. The positions are at the Assistant Professor level, but appointment at higher rank will be considered for candidates with exceptional ability and appropriate experience.

Major departmental equipment available includes an electron microprobe, SEM, X-ray diffraction, ICP, AA, mass spectrometers, IBM 3081 and 3033 mainframe computers and Department VAX 11/750, along with a wide variety of microscopes and accessories. Ongoing research related to the above positions includes studies of greenstone belt volcanics, archean sediments, ocean floor and flood basalts, fission-track dating, K-Ar and Ar-Ar, oxygen isotope mass spectrometry, carbonate geochemistry, and clay mineralogy.

Applicants should submit a vita, representative reprints, and a statement of teaching and research interests and arrange for three letters of recommendation to be sent to: Chairman PMV Search Committee, Department of Geology, Louisiana State University, Baton Rouge, LA 70803.

LSU is an equal opportunity/affirmative action employer.

Geochemistry. The University of California, Davis will fill a permanent, tenure track, faculty position at the assistant professor level beginning Fall, 1985. Candidates having interests in isotope geochemistry and/or the geochemistry of economic deposits are especially encouraged to apply but other specialities in geochemistry will be considered. A PhD degree is required. Responsibilities include teaching at the undergraduate and graduate levels, and research in geochemistry.

Applicants should submit complete vita, a statement of research and teaching interests and the names of three referees. Deadline for application is January 15, 1985. Inquiries and applications should be directed to: Howard W. Day, Department of Geology, University of California, Davis, CA 95616.

The University of California is an equal opportunity/affirmative action employer.

Northern Arizona University/Department Chairperson. Chairperson, associate or full professor, Department of Geology, Northern Arizona University, beginning summer 1985. Specialty open but preference will be given to applicants with a strong background in tectonics and reflection seismology. Applicants must be capable of interacting professionally with an active and diverse faculty of 14 geologists and geophysicists. Candidates should expect to continue an active research program, should have administrative capabilities and a dedication to quality teaching. The Department has been granted planning authority for a Ph.D. program so it is essential the successful candidate possess the desire to guide the Department through the final planning stages. NAU has a traditional emphasis on field problems in the Colorado Plateau and adjacent areas; we are expanding our analytical facilities to improve theoretical and experimental capabilities. Salary will be competitive and negotiable. [illegible] Send curriculum vitae, statement of research interests and names of four professional references to Search Committee—Code C, Department of Geology, Box 6030, Northern Arizona University, Flagstaff, AZ 86011.

Northern Arizona University is an equal opportunity/affirmative action employer.

University of South Carolina. Two year postdoctoral research assistant position anticipated. Person should have a strong background in many aspects of complexly deformed regions along with an interest in geologic mapping and integration of diverse kinds of geologic and geophysical data. Starting date as early as January 15, 1985. Closing date for applications December 31, 1984. Applications with vitae, interests and possible references should be sent to Prof. Robert D. Hatcher, Jr., Department of Geology, University of South Carolina, Columbia, SC 29208.

The University of South Carolina is an affirmative action/equal opportunity employer.

Chairperson/The University of Tulsa, Department of Geosciences. Nominations and applications are invited for the position of Chairperson. Candidates should have a Ph.D. and a distinguished record of teaching and research. Leadership and administrative skills and experience to interact effectively with academics, industry and alumni are required.

The department of geosciences has ten faculty members and is located in a new teaching and research complex. There is a strong emphasis on soft rock geology and exploration geophysics in the department which has grown steadily in the last decade. Equipment includes a VAX 11-750 computer with an array processor and seismic data processing software, SEM, Microprobe, XRF, XRD, gas chromatographs and a mass spectrometer. Library resources which are supported by "Petroleum Abstracts" are excellent.

Nominations and applications should be sent to: Colin Barker, Department of Geosciences, University of Tulsa, 600 South College, Tulsa, Oklahoma 74104 by January 15, 1985.

The University of Tulsa is an equal opportunity/affirmative action employer.

Seismologist/University of Utah. The Department of Geology and Geophysics at the University of Utah seeks applicants for a tenure track faculty position in seismology at the assistant to associate professor level. Applicants with backgrounds and specialties in seismic imaging, seismic reflection or theoretical seismology will be given preference. The individual will be expected to teach undergraduate and graduate courses and to pursue an active research program with graduate students. A strong imaging laboratory with a VAX 11/780, FPS array processor, plotters, and processing and synthetic seismogram software is available to the successful candidate. Current research in seismology includes: earthquake research utilizing a PDP 11–70 computer, monitoring of the Intermountain seismic belt by an 85 station telemetered network utilizing an on-line PDP 11–34 computer; major experiments in seismic refraction and reflection profiling for crustal structure; and allied research in tectonophysics. The opportunity exists to participate with several other faculty in an integrated program of tectonics, seismology and sedimentology directed toward crustal studies and petroleum exploration. The geophysics component of the department has active research and teaching programs in electrical and electromagnetic methods, thermal properties of the earth, potential fields, and seismology. The department has close associations with the numerical analysis and data processing groups in computer science, electrical engineering and mathematics. The closing date for applications is December 31, 1984, and the appointment date is September 15, 1985. A Ph.D. is required for this position. Applicants should send a vita, transcripts, a letter describing his/her research and teaching goals and names of five persons for reference. Qualified persons should send their applications to William P. Nash, Chairman, Department of Geology and Geophysics, University of Utah, Salt Lake City, Utah 84112-1183.

The University of Utah is an equal opportunity/affirmative action employer.

Faculty Position in Structural Geology/Tectonics. The Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, has a tenure track opening at the Assistant or Associate Professor level in the area of structural geology/tectonics. The position will be filled for the beginning of the Fall 1985 term. The department currently has 31 full-time faculty, including 12 geologists and geophysicists.

The successful applicant will be expected to have completed the PhD degree. Courses to be taught include undergraduate structural geology as well as courses in structural analysis, tectonics, or other areas of research activity. He or she additionally will be expected to develop a vigorous program of sponsored research and to direct graduate student research projects at the MS and PhD level.

Please send complete resume and the names of at least three references to V.V. Cavaroc, Search Committee Chairman, Department of MEAS, North Carolina State University, Raleigh, NC 27695–8208; phone (919) 737-2212. Applications will be considered as received, with a closing date of January 15, 1985.

North Carolina State University is an equal opportunity/affirmative action employer.

Ph.D. Fellowships/Louisiana State University. Applications are invited from prospective Ph.D. students in all fields of geology and geophysics for fellowships in the Department of Geology, Louisiana State University. The stipends, provided by Arco, Exxon, and the LSU Alumni Federation, range from $10,000 to $13,500 per year; the awards are made on an annual basis and are renewable for up to three years. One of the benefits of these fellowships is a reduction of tuition and fees to about $100 per semester.

Applications (plus transcripts, GRE scores, and three letters of recommendation) must be received by March 15. For the Alumni Federation Fellowships, however, the Departmental deadline for receipt of application package is January 7.

Application materials and further information on the graduate program can be obtained from:

Barun K. Sen Gupta
Director of Graduate Studies
Department of Geology
Louisiana State University
Baton Rouge, LA 70803–4101.

Louisiana State University is an equal opportunity/affirmative action employer.

Graduate Fellowships/University of Oklahoma. The School of Geology and Geophysics offers fellowships for Ph.D. study in each of the following broad disciplines: (1) origin, ascent, and fractionation trends in magmas and associated ore deposits; (2) formation and tectonic evolution of continental lithosphere, including geophysical properties and structures of the upper crust; and (3) sedimentary processes, including organic and inorganic diagenesis, evolution of hydrocarbons, and correlation using biostratigraphic methods. Average fellowship stipends are for $10,000/9 month and are renewable annually on a competitive basis. Fellowship awards include a waiver of out-of-state tuition and fees.

The School of Geology and Geophysics presently consists of 19 full-time faculty. Research facilities in the school include a stable isotope laboratory; organic geochemistry laboratory; computer automated X-ray diffraction and fluorescence equipment; atomic absorption and neutron activation analysis equipment; scanning electron microscope with energy dispersive analyzer; transmission electron microscope; fission-track dating laboratory; fluid inclusion microthermometry laboratory; 2 kb hydrothermal laboratory for phase equilibrium experiments; high-pressure rock mechanics laboratory; paleomagnetic laboratory with a cryogenic magnetometer and thermal and AF demagnetization apparatus; 24-, 48-, and 192-channel digital seismic recording systems; a VAX 11-785 computer with high-resolution graphics and image-display terminals, with seismic and image processing software; and a 84,000 volume geology and geophysics library located in the department.

For further information on faculty and active research projects, contact: Kevin Crowley, School of Geology and Geophysics, University of Oklahoma, 830 Van Vleet Oval, Norman, OK 73019.

Congressional Science Fellowship. Opportunity for a one-year assignment (September to August) or the staff of a congressional committee or a House or Senate member as an advisor on a wide range of scientific issues affecting public policy questions.

Individuals who are AGU members and U.S. residents are invited to apply. A broad background in science is expected, as the various duties entailed require the applicant to be articulate, literate, flexible, and able to work well with people from diverse professional backgrounds.

Public policy background is not required although such experience and/or demonstratable interest in applying science to the solution of public problems is desirable.

The fellowship carries with it a stipend of up to $28,000 plus travel allowances.

How to apply:

Candidates should submit a letter of intent, a curriculum vitae, and three letters of recommendation. The letter of intent should include a statement of why the fellowship is desired, how you qualify for it, what issues and congressional situations interest you, what role you envision as a congressional science fellow, and what outcome you hope for in relation to your career goals. The individuals from whom you request letters of recommendation should discuss not only your professional competence, but also other aspects of your background that make you particularly qualified to serve as a Congressional Science Fellow.

Texas Tech University/Geophysicist or Clastic Sedimentologist. The Department of Geosciences at Texas Tech University seeks applications for a tenure track position in the fields of geophysics or clastic sedimentology to begin August 1985. Rank and salary will be commensurate with qualifications. The Ph.D. is required. Entry-level applicants will be given preference. The primary responsibility would be to teach both graduate and undergraduate courses in geophysics or depositional systems and sedimentology, his/her specialty, and introductory geology. The person will be expected to initiate a research program and to direct MS and Ph.D. graduate students. Send a letter of application with complete curriculum vitae and names of three references to Dr. Alonzo D. Jacka, Chairman of Geosciences, P.O. Box 4109, TTU, Lubbock, TX 79409.

Texas Tech is an equal opportunity/affirmative action employer. Applications deadline: January 31 1985.

Middlebury College/Metamorphic Petrologist. The Department of Geology seeks a metamorphic petrologist with an interest in tectonics. The regular (tenure-track) entry-level position requires the PhD and begins in the fall of 1985.

The 4-member department maintains active research and an on-going field and lab program with students in tectonics, petrology, and oceanography. Teaching responsibilities normally include 5 semester-courses, a 1-month winter term course, and supervision of senior research. The department has an XRD/XRF laboratory and an automated electron microprobe.

Send application, including resume, research interests, transcripts, and 3 current letters of reference to: Brewster Baldwin, Chairman, Department of Geology, Middlebury College, Middlebury VT 05753. Application deadline is February 1, 1985.

Middlebury College is an equal-opportunity employer.

University of Miami/Rosenstiel School of Marine and Atmospheric Science. The Division of Marine and Atmospheric Chemistry is embarking on a major expansion program that includes the construction of new laboratory facilities which will be completed in mid-1985. In accordance with this program, four tenure track positions at the rank of assistant, associate or full professor are available for qualified persons with backgrounds in the areas of stable isotope geochemistry, water-sediment chemistry, atmospheric chemistry and the modeling of atmospheric and/or ocean chemical processes. Division members are engaged in a broad spectrum of research programs including field studies carried out at continental and island sites and aboard aircraft and ships. While all qualified persons are encouraged to apply, we would particularly welcome applications from persons interested in pursuing field-related research, especially aboard ships.

A curriculum vitae, a summary of teaching and research experience, a brief statement about future research interests and the names of three references should be sent to: Dr. Joseph M. Prospero, Chairman, Division of Marine and Atmospheric Chemistry, University of Miami, RSMSA, 4600 Rickenbacker Causeway, Miami, FL 33149–1098, by January 15, 1985.

The University of Miami is an equal opportunity/affirmative action employer.

University of Wisconsin—Madison. The Department of Geology and Geophysics invites applications for an anticipated tenure track position at the assistant professor level in applied geomorphology and/or hydrogeology commencing in August 1985. The applicant should be committed to developing a strong research program as well as teaching undergraduate courses in some aspects of engineering and environmental geology. The Ph.D. is required. Applicants with course work in engineering and an interest in the field application of geologic principles are especially encouraged to apply. Send letter of application outlining your professional goals, transcripts, resume, copies of publications, and three letters of reference to Dr. Mary P. Anderson, Department of Geology and Geophysics, Weeks Hall, University of Wisconsin, Madison, WI 53706. Closing date is January 1, 1985.

The University of Wisconsin is an equal opportunity/affirmative action employer.

Satellite Altimetry: Department of Commerce, National Oceanic and Atmospheric Administration (NOAA). The National Ocean Service, Office of Charting and Geodetic Services announces a vacancy for the position of Geodesist, GS-1372-13. The position is in the Satellite and Ocean Dynamics Section of the National Geodetic Survey, Rockville, Maryland. This research position will involve analysis of satellite altimeter data for application to ocean dynamics and geodynamics. Applicants should have a detailed knowledge of altimetry, marine geodesy, and physical oceanography, including concepts of geostrophic circulation and planetary wave theory. Investigations will be concerned with sea height variability, equatorially trapped waves, assimilation of altimeter data into numerical models, and other topics of importance to established national programs in ocean and climate studies. The position requires a demonstrated ability to do scientific research as evidenced by publications in the literature. A Ph.D. in physical sciences or equivalent is desirable. Persons interested in applying may request a copy of the vacancy announcement which contains qualification requirements, by writing to Ms. Louise Turner, RAS/DC25, NOAA, National Ocean Service, Rockville, Maryland 20852, or by calling 301-443-8995. Applications should be submitted on Standard Form 171. Closing date for applications is 12-10-84.

Department of Commerce is an equal opportunity employer. U.S. citizenship required.

Assistant Professorship in Obeservatioanl Coastal Dynamics/University of North Carolina Institute of Marine Sciences, Morehead City. Tenure track position for a physical scientist with interests in neashore (continental shelf and/or estuarine) cirualtion will be availabel on July 1, 1985. This will be a research positon, carrying a nine-month state supported salary commensuarte with experience. The appointee will be expected to develop and carry out a field program in nearshore circulation. This person will be staffed at a research laboratory where programs related to coastal dynamics are underway. These programs include sudies of sediment dynamics, sediment/water chemical exchanges, plankton patchiness and larval dynamics. The appintee will also interact with faculty and students in an academic Curriculum in Marne Sciences at Chappel Hill. Faculty in this unit conduct research on carbonate platform geology, Gulf Stream dynamics and sediment/water chemical exchanges.

Interested applicants should send a letter describing their research intersts, a curriculum vitae and names of forur references to Dirk Frankenber, Director Institute of Marine Sciences, 3407 Arendell Street, Morehead City, NC 28557 by January 4, 1985.

The University of North Carolina is an affirmative action/equal opportunity employer.

Chief, Land Sciences Branch: U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), GS-1301–14, Salary Range $42,928 to $55,807, Suitland, MD. The Climate and Earth Sciences Laboratory, National Environmental Satellite, Data, and Information Service (NESDIS), NOAA, announces a vacancy for the position of Chief, Land Science Branch. The Climate and Earth Sciences Laboratory is repsonsible for applying satellite observations to problems in the atmospheric, oceanic and land sciences. The Land Sciences Branch uses imagery and radiometric observations from meteorological and land resource satellites for studies in climatology, hydrology, glaciology, and agriculture. It is anticipated that the Land Sciences Branch will participate in the recently initiated International Satellite Land Surface Climatology Project. Branch scientists: 1) develop algorithms for deriving land surface variables from satellite radiance observations, 2) test, validate and apply these algorithms, and 3) perform research on land surface processes using the satellite based measurements. Examples of land variables of interest include snow and ice, skin temperature, surface radiation budget, soil moisture, vegetation cover, and hydrological parameters.

The successful applicant will direct the activities of the Branch and manage its resources, including research grants/contracts with external institutions. He will also actively engage in personal research in one of the land science areas. The successful applicant must have a record of scientific achievement on the application of remote sensing to the above stated problems, as evidenced by publications in the scientific literature. The position requires a Ph.D. in the physical sciences or equivalent and at least five years of relevant experience. Familiarity with programming of mainframe computers and experience with interactive image processing systems are also desirable.

Persons interested in applying must request a copy of the vacancy announcement, which contains qualification requirements, by writing to NOAA, FB4, Room 2051, Washington, D.C. 20233, ATTN: RAS/DC24, Barbara Jones, or calling 301-763-1986. Applications should be prepared on Standard Form 171.

Department of Commerce is an Equal Opportunity Employer. U.S. Citizenship required.

Faculty Positions/Arizona State University, Department of Geology. Applications are invited for two tenure track positions, beginning in August of 1985 at the rank of Assistant or Associate Professor. The selected candidates will be expected to display excellence in teaching and to develop vigorous programs of research on important geological problems. Research areas which complement our existing strengths, especially igneous, metamorphic, or sedimentary petrology, are the most desirable. Preference will be given to applicants with a demonstrably strong quantitative approach to problems of wide interest. Please send a detailed statement of research and teaching interests and a resume with names of four references by January 15, 1985, to Paul Knauth, Chairman, Department of Geology, Arizona State University, Tempe, AZ 85287.

Arizona State University is an equal opportunity/affirmative action employer.

The Johns Hopkins University/Paleontologist. The Department of Earth and Planetary Sciences invites applications for a tenure-track faculty position, effective July 1, 1986, for a paleontologist whose research will strengthen the link between paleontology and sedimentology programs. The appointee will be expected to develop an innovative research program, and responsibilities will include undergraduate and graduate teaching and the supervision of doctoral candidates.

To apply, send curriculum vitae, publications list, and the names of at least three referees to Dr. John M. Ferry, Department of Earth and Planetary Sciences, The Johns Hopkins University, Baltimore, MD 21218, U.S.A. The application deadline is January 15, 1985.

The Johns Hopkins University is an equal opportunity, affirmative action employer.

Seismologist/University of Illinois. Applications are solicited for a tenure-track position at the Assistant Professor level in seismology. A creative individual is sought who will develop a research program that complements our existing programs in seismology (currently emphasizing source properties), geodynamics, tectonics, and rock/mineral physics. An excellent research environment and outstanding facilities are available both in the Department and the University. A Center for Super Computer Research and Development is presently being formed at the University. In addition, our campus is the site of a proposed regional computational facility. Opportunity exists to interact with the department of Theoretical and Applied Mechanics. The position is expected to be filled as early as Fall, 1985. Salary is commensurate with experience; a PhD is required. The successful candidate is expected to participate in teaching and advising at the graduate and undergraduate levels. For equal consideration, interested individuals should send curriculum vitae, list of publications, statements of research interests and names of three or more references by December 15, 1984 to:

Professor Albert T. Hsui
Department of Geology
University of Illinois at Urbana-Champaign
1301 W. Green Street
Urbana, Illinois 61801
Tel: 217/333-7732 or 333-3542.

The University of Illinois is an equal opportunity/affirmative action employer.

Faculty Position/Michigan Technological University. The DEPARTMENT OF GEOLOGY AND GEOLOGICAL ENGINEERING invites applications for a one year full-time position in teaching and research starting in the fall 1985. This is a sabbatical replacement and there is a possibility of a second year extension. The successful candidate will be expected to teach undergraduate classes in some area of geology/mineralogy/petrology and a graduate seminar in his/her specialty, as well as pursue research in some mutually acceptable area of geology/geological engineering or geophysics and interact with faculty and students in on-going programs. The department has 12 faculty, is situated in a spectacular natural environment and has excellent facilities for petrological, geochemical, geophysical and geotechnical research. Applicants with enthusiasm for teaching and graduate research are urged to send a detailed resume, names of three references and statement of research interests to: Professor Gordon F. Frantti, Acting Department Head, Department of Geology and Geological Engineering, Michigan Technological University, Houghton, Michigan 49931.

Michigan Technological University is an equal opportunity educational institution/equal opportunity employer.

Paleobiologist/Earth and Space Sciences, UCLA. Faculty appointment effective academic year 1985–86, with interests in one or more of the following areas: (1) paleobiology (any subdiscipline, including biostratigraphy); (2) processes of biologic evolution; (3) development of ecosystems during geologic time; and (4) biochemical evolution. Depending on the candidate's interests, joint appointment between the Department of Earth and Space Sciences, the Center for the Study of Evolution and Origin of Life, or the Institute of Geophysics and Planetary Physics, and/or other academic departments may be considered. The position is open to exceptionally well-qualified candidates at any academic rank or level of postdoctoral experience. The prime criteria for selection will be outstanding intellectual ability, expertise in the relevant scientific disciplines, and excellence in research and teaching. To apply, please forward your curriculum vitae, a listing of three or more references (with phone numbers), and a one-page description of your background and experience in the relevant problem areas, before February 15, 1985 to: Chair, Paleobiology Search Committee, Department of Earth and Space Sciences, University of California, Los Angeles, CA 90024.

Applicants should request that three reference letters be sent directly to the search committee.

The University of California is an equal opportunity employer; qualified women and/or members of minorities are especially invited to apply for this position.

Department of Geosciences/University of Houston. The Department of Geosciences has permission to hire at least one geophysicist to complement the 16 members of our faculty (3 in geophysics). This is a tenure track position with a starting date of August 1985. We are particularly interested in talking with individuals with a strong background in: theoretical seismology, experimental seismology, applied seismology. Salary and rank will be commensurate with experience. Applicants should submit: (1) a curriculum vita; (2) a brief statement of research interests; (3) a brief statement of teaching interests; (4) three letters of recommendation; (5) copy of graduate transcripts.

John C. Butler, Geosciences
University of Houston, University Park
Houston, Texas 77004

Stuart A. Hall will be at the AGU meetings in December and would like to talk with interested applicants.

The University of Houston is an equal opportunity/affirmative action employer.

Petrologist/Virginia Polytechnic Institute and State University. The Department of Geological Sciences at Virginia Tech invites applications for two tenure track faculty appointments in Igneous or Metamorphic Petrology. Applicants must demonstrate a strong research record in quantitative petrology; preference will be given to those with experience in the theoretical and experimental aspects of petrology. All faculty members at Virginia Tech are expected to provide quality teaching at the undergraduate and graduate levels, supervise M.S. and Ph.D. theses, and conduct an active program of research and publication.

Applicants should send a letter of application, academic vita and names and addresses of three references to:

D.A. Hewitt
Department of Geological Sciences
Virginia Tech
Blacksburg, VA 24061.

The appointments will begin in September 1985 and candidates are expected to have completed requirements for the Ph.D. by that time. The deadline for receipt of applications is January 1, 1985.

Virginia Tech is an equal opportunity/affirmative action employer.

School of Physical Sciences: Research Associate in Theoretical and Space Physics/La Trobe University. A Research Associate (Experimentalist or Theorist) is required to work on the irregular structure of the ionosphere at mid-latitudes. The appointee will be a member of the group consisting of F.C. Butcher, F.A. Cohen, K.D. Cole, P.L. Dyson and P.R. Hammer. The group has a Digisonde 256, Fabry-Perot interferometer, Faraday polarimeter, HF Doppler system, geomagnetic pulsation recorder and other equipment. The position is funded by the Australian Research Grants Scheme commencing in 1985 for a period of two years.

CLOSING DATE: January 14, 1985. REF. NO. A00300100

SALARY: Research Assistant 1 A$22,300—A$23,905

Applications (marked confidential) including reference number, names of three referees and curriculum vitae should be forwarded to the Staff Officer, La Trobe University, Bundoora, 3083. Melbourne, Australia.

University of California/Graduate Assistantships. University of California, Santa Barbara Graduate Fellowships, Teaching Assistantships and Research Assistantships in geology, geophysics, marine geophysics. Special Regents' Fellowships with four years of full support available to outstanding applicants. The department stresses a close interplay between geology and geophysics as well as field research opportunities both on land and at sea. Majors in physics, engineering and mathematics as well as geological sciences welcome. Apply to:

Professor Ken C. Macdonald
Graduate Advisor
Department of Geological Sciences
University of California
Santa Barbara, CA 93106.

High Altitude Observatory Scientific Visitor Program/NCAR. Scientific visitor appointments at the High Altitude Observatory are available for new and established Ph.D's for up to one year to carry out research in solar physics, solar-terrestrial physics, and related subjects. Applicants should provide a curriculum vitae, including education, work experience, publications, the names of three scientists familiar with their work, and a statement of their research plans. Applications must be received by 15 January 1985 and they should be sent to: The HAO Visitor Committee, High Altitude Observatory, National Center Atmospheric Research, P.O. Box 3000, Boulder, Colorado 80307–3000.

NCAR is an Equal Opportunity/Affirmative Action Employer.

University of Washington/Geophysics. Applications invited for a research faculty opening at the Assistant Professor level. Candidates are expected to establish innovative, high quality research programs in rock and mineral physics and to obtain funding (including salary) to maintain programs which should complement and/or augment existing programs in rock and mineral physics at the UW of Drs. J.M. Brown and V. Sato-Sorensen.

Send resume and four letters of reference prior to January 15, 1985 to: Professor R.T. Merrill, Geophysics Program AK-50, University of Washington, Seattle, WA 98195.

The University of Washington is an affirmative action/equal opportunity employer.

Seismologist/University of Puerto Rico. The University of Puerto Rico and the Center for Energy and Environmental Research seek applications for a position in the field of seismology. The position is for part-time instruction at the University of Puerto Rico, Cayey and investigation of data from a 20-station short period, digital seismic network in Puerto Rico and the Virgin Islands. The applicant is expected to have demonstrated ability to work with data from a seismic network or ability to work on seismic hazard problems.

All interested persons should submit a letter of application, a detailed resume of educational experience and a summary of interests to:

Dr. William R. McCann
Lamont-Doherty Geological Observatory
Palisades, New York 10964
Telephone: 914-359-2900 ext. 377

Sedimentologist-Oceanographer/Texas A&M University. Applications are invited for a tenure track faculty position in the general field of marine sedimentology. The position will involve graduate level teaching and supervision of graduate student research. The successful applicant will have demonstrated excellence in or a strong potential for independent research in the field of marine sedimentation. The position is available beginning September 1, 1985. Salary and rank will be commensurate with experience and qualifications. Applicants are invited to submit curricula vita, copies of publications, names of three persons who may serve as references, and a letter outlining the applicant's teaching and research interests by December 31, 1984, to Robert O. Reid, Distinguished Professor and Head, Department of Oceanography, Texas A&M University, College Station, Texas 77843.

Texas A&M University is an affirmative action/equal opportunity employer.

Faculty Positions/The Pennsylvania State University. The Department of Geosciences invites applications for three (3) tenure track faculty positions in any of several fields of specialization. The faculty rank associated with each position is presently open, although salary funds currently available are sufficient for, at most, one senior full professorship. The successful candidates must be, or have demonstrated the potential to become, nationally recognized leaders in their fields. They must also have an interest in teaching and advising graduate and undergraduate students. Instructional and research areas in which particular needs have been identified include, but are not necessarily limited to: aqueous geochemistry, with emphasis on the kinetics of low-temperature rock-water interactions; experimental petrology, with emphasis on the equilibrium and kinetic properties of petrological systems; heavy isotope geochemistry, with emphasis on element distribution systematics and their geological applications; hydrogeology, with emphasis on the physics of fluid flow and mass transport through porous media; mineral physics/mineralogy, with emphasis on petrological applications of crystallochemical methods; rock physics, with emphasis on the dynamical properties of upper-crustal rocks; sedimentary geochemistry, with emphasis on diagenesis of fine-grained sediments and organic matter; and structural geology, with emphasis on regional tectonics.

The selection of persons to fill these three positions will be based in part on the extent to which their future research efforts will complement and further strengthen our programs in Geochemistry and Mineralogy, Geology, and Geophysics. Qualified persons should, therefore, include a brief description of their future research objectives with their resumes and the names of three references to:

C. Wayne Burnham, Head
Department of Geosciences
The Pennsylvania State University
503B Deike Building
University Park, Pennsylvania 16802.

The deadline for applications is April 30, 1985.

An Equal Opportunity/Affirmative Action Employer.

Carnegie Institution of Washington/Postdoctoral Fellows 1985–86, Department of Terrestrial Magnetism. Endowed postdoctoral fellowships in private institution, emphasizing maximum freedom of research in areas of seismology, geophysics, isotope and trace element geochemistry, cosmochemistry, accelerator mass spectrometry, planetology, and star and planet formation. Renewable for second year. Completed applications due February 1, 1985. For information write Fellowship Committee (I), Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Road, N.W., Washington, D.C. 20015.

Women and minority candidates encouraged. Carnegie Institution of Washington is an EOE/AAE.

Assistant/Associate Professor of Geophysics. Applications are invited for a tenure track position as assistant or associate professor of geophysics in the College of Oceanography at Oregon State University to complement the present eight-member geophysics faculty. Candidates must have a PhD or equivalent and a demonstrated ability to conduct independent research in theoretical or observational geophysics sustained by external research funding. Most solid earth geophysics research specialties will be considered. Duties will include teaching graduate courses, supervising graduate students and developing a grant-funded research program. Those interested should submit a resume, names of three references and a brief statement of research plans by February 28, 1985 to:

Acting Dean
College of Oceanography
Oregon State University
Corvallis, OR 97331.

Oregon State University is an affirmative action/equal opportunity employer and complies with Section 504 of the Rehabilitation Act of 1973.

Postdoctoral and Research Associate Positions/INSTOC. The Institute for the Study of the Continents (INSTOC) invites applications for postdoctoral and research positions in programs involving study of the continental crust, including COCORP, or to initiate new programs of crustal study. The Ph.D. is required, and experience in geophysics or geology is desirable. Send vitae, list of publications, and letters of recommendation to Professor Jack Oliver, Institute for the Study of the Continents, Snee Hall, Cornell University, Ithaca, NY 14853.

An equal opportunity/affirmative action employer.

POSITIONS WANTED

Physical Oceanographer. M.S. 1983. Experience in hydrographic data acquisition and analysis in the SW Atlantic and NE Pacific. Seeking a position as research assistant in academic institution, industry or government. RMO, 2855 Three Mile Lane, McMinnville, OR 97128.

Physical Oceanographer. Recent PhD. Specializing in Air-Sea Interactions with primary interest in Remote Sensing Applications. Several publications. Seeking industrial, academic research or government position. Box 029, American Geophysical Union, 2000 Florida Avenue, N.W., Washington, D.C. 20009.

STUDENT OPPORTUNITIES

Graduate Teaching and Research Assistantship in Marine Environmental Sciences and Coastal Oceanography. Opportunities for graduate study with graduate and research assistantships available for students interested in MS and PhD degree programs in marine environmental sciences and coastal oceanography. Awards cover tuition and academic year stipend up to $7,883. Additional summer support also available up to $3,000. Write: Graduate Programs Chairman, Marine Sciences Research Center, SUNY Stony Brook, Stony Brook, NY 11794.

SERVICES, SUPPLIES, COURSES, AND ANNOUNCEMENTS

Availability of Request for Cooperative Agreement Applications: RFA# 1000-A. Acid Deposition Monitoring Support for Effects Research/U.S. Environmental Protection Agency. Application Receipt Date: January 18, 1985.

The U.S. Environmental Protection Agency (E.P.A.), under the National Acid Precipitation Assessment Program (NAPAP), is announcing the availability of funds for fiscal year 1985 for awarding a cooperative agreement(s) to support acid deposition monitoring stations to enhance the results of acid deposition effects studies. The research areas of primary interest involve studies of acid deposition (including ambient air pollution) mechanisms and rates of damage to forest ecosystems, calibrated watersheds and building materials. EPA has approximately one million dollars available to award cooperative agreement(s) to support this project. Support for this program may be for a period extending up to five years. In order to receive a copy of the RFA and further information contact:

Dr. Clarice E. Gaylord
Research Grants Staff
Office of Research & Development
U.S. Environmental Protection Agency
401 M Street, SW
Washington, D.C. 20460
Telephone 202-382-7173.

Meetings

Announcements

Precipitation Measurements

April 1–3, 1985 Workshop on the Correction of Precipitation Measurements, Zurich. Organizers: Swiss Federal Institute of Technology (ETH), International Association of Hydrological Sciences, World Meteorological Organization. (Boris Sevruk, Hydrology Section, Department of Geography ETH, Winterturerstrasse 190, 8057 Zürich, Switzerland.)

The deadline for the submission of abstracts is January 31, 1985.

The aim of the workshop is to improve and to undertake efforts to standardize the procedures used in the correction of precipitation data. Suitable topics for papers for presentation include corrections currently applied in particular countries, special problems of correction, methods for the estimation of errors due to the wind field deformation above the precipitation gage orifice, and errors due to splashing, wetting, evaporation, and snow blowing. A poster exhibition is also planned. In the final discussion of the workshop, recommendations will be formulated for standardized correction procedures.

Meteorology and Oceanography

June 12–14, 1985 19th Annual Canadian Meteorological and Oceanographic Society Congress and Annual General Meeting: Modeling in Meteorology and Oceanography, Montreal. (Organizers: Canadian Meteorological and Oceanographic Society, l'Université du Québec à Montréal. (Jean-Guy Cantin or Richard Moffet, 100 Alexis-Nihon Blvd., 3rd Floor, Montreal, Quebec, Canada H4M 2N8; tel.: 514-333-4551.)

The deadline for the submission of abstracts is February 1, 1985.

Contributions are sought on theoretical and practical aspects of modeling atmosphere-ocean interactions, waves in oceans or atmosphere, atmospheric and oceanic circulation, limnology, climatology, operational meteorology, cloud dynamics, and transport and diffusion of pollutants. Sessions on meteorological and oceanographical topics other than modeling also will be organized, depending on contributions.

High-Temperature Heat Exchangers

August 26–30, 1985 17th International Symposium on High-Temperature Heat Exchangers, Belgrade, Yugoslavia. Sponsor: International Centre for Heat and Mass Transfer. (Y. Mori, Department of Mechanical Engineering, University of Electro-Communications, 1-5-1, Chofugaoka, Chofu, 182 Tokyo, Japan.)

The deadline for the submission of 500–700-word abstracts is January 20, 1985.

The purposes of the symposium are to bring together the results of basic and applied research on heat and mass transfer suitable for use in the field of high-temperature heat exchangers and to examine the problems encountered in the development of various types of high-temperature heat exchangers. Topics for papers include high-temperature regenerators for gas turbine and fuel cell plants, high-temperature heat exchangers in the Stirling cycle and other engines, ceramic heat exchangers (of the plate fin, tubular, and rotary types), high-temperature heat transfer augmentation, and new ceramics and superalloys for high-temperature heat exchangers.

GAP

Separates

To Order: The order number can be found at the end of each abstract; use all digits when ordering. Only papers with order numbers are available from AGU. *Cost:* $3.50 for the first article and $1.00 for each additional article in the same order. Payment must accompany order. Deposit accounts available.

Send your order to:
American Geophysical Union
2000 Florida Avenue, N.W.
Washington, D.C. 20009

Exploration Geophysics

0930 Seismic methods
A GEOPHYSICAL STUDY ON THE ABU GHARADIG BASIN, EGYPT
Ghareeb M. Awad (Gatty Oil Canada, 1198 Abbeydale Drive N.E., Calgary, Alta., Canada T2A 6L1)

The area of study comprises one of the most hydrocarbon-potential basins of the Egyptian Western Desert, the Abu Gharadig basin.

Major marine transgression and regression cycles dominated the territory during different geologic times. Those depositional cycles, together with at least three tectonic cycles—the end of the Paleozoic Hercynean, the close of the Jurassic until the Late Cretaceous, and the close of the Cretaceous until Mid-Tertiary—resulted in a highly deformed, thick sedimentary cover.

A study of the geophysical anomalies of the basin, including those indicated by aeromagnetic, gravity, and seismic data as well as the study of about 60 deep wells drilled within and around the Abu Gharadig basin, has revealed that the major tectonic disturbances of the area were caused by basement complex block faulting. These major tectonic disturbances have produced great variations in the thickness and distribution of the various geologic units throughout the region.

Aeromagnetic anomalies and the wells which reached the basement indicate great variations in the depths and type of the basement complex and the presence of major intrusions in the region. The major fracturing is indicated to be mainly along east-west, west-northwest and east-northeast directions.

The Bouguer gravity anomalies indicate major basement fracturing as well as variations in sedimentary patterns, erosion, and subsequent tectonic disturbances.

The most obvious anomalous trends on the gravity map, based on frequency and amplitude, are the northeast to east-northeast, the east-west and the west-northwest. The main Abu Gharadig depositional center does not show sharp variations because of the homogeneity of the near-surface rocks and the great basement depth (20 000–40 000 ft).

Seismic interpretation has confirmed the presence of all these fracturing trends. It also identified some major structural trends. These are closely related to the depositional centers, and represent potential drilling locations, especially those associated with Late Cretaceous-Tertiary active contemporaneous faulting.
GEOPHYSICS, VOL. 50, NO. 1

0930 Seismic methods
PRESTACK INVERSION WITH PLANE-LAYER POINT SOURCE MODELING
Alastair D. McAulay (Texas Instruments, P.O. Box 226015, MS 238, Dallas, TX 75266)

Prestack inversion with point source plane-layer modeling has many advantages over poststack or normal incidence inversion. For example, it permits the determination of absolute compressional and shear velocities, density variation, and the accurate accounting of interbed and surface multiples. I neglect shear effects in this paper by assuming that they are adequately suppressed by velocity filtering. In the forward modeling step, a spherical wave expansion into plane waves is used to account for the point source. The plane-wave reflection response for a set of plane layers is extended to the nonnormal incidence case. I use a Hankel transform to account for cylindrical symmetry. Generalized linear inversion is used because the fast recursive approaches available for normal incidence inversion are no longer applicable. I provide the derivation for the required matrix, and I take into account the band-limited nature of the data in frequency, time, and space.

I demonstrate that moveout of events on realistic simulated prestack data enables the determination of absolute compressional velocity in the velocity depth profile, even though the data are band-limited in frequency. I assume that preprocessing has adequately removed the shear and surface effects and that density is constant. Low frequencies in the velocity profile may be obtained more accurately than with velocity analysis used for stacking, because interbed multiples and other modeling phenomena are accounted for in the computation. Autoregressive modeling procedures that predict into the low frequencies of the velocity profile are also less accurate and cannot generate absolute velocity. I suggest future research leading to cost-effective inversion of real data.
GEOPHYSICS, VOL. 50, NO. 1

0930 Seismic methods
ANALYSIS OF A GAS HYDRATE OFF SOUTHWEST MEXICO USING SEISMIC PROCESSING TECHNIQUES AND DEEP SEA DRILLING PROJECT LEG 66 RESULTS
Barclay P. Collins (Formerly Gulf Research and Development Company, Pittsburgh, PA; presently Gulf Oil Exploration and Production Company, P.O. Box 1392, Bakersfield, CA 93302) Joel S. Watkins

Analysis of a reprocessed seismic reflection line and results from Deep Sea Drilling Project Leg 66 off the southwest coast of Mexico reveal a bottom simulating reflector (BSR) associated with the equilibrium phase boundary of methane hydrate. Several seismic processing techniques were used to accentuate the lateral continuity of the BSR and to delineate the top and base of a 200–700 m thick concentrated hydrate layer extending about 20 km parallel to the slope of the inner trench wall in water depths ranging from 2 250–4 500 m. Direct seismic indicators below the BSR and geochemical evidence imply small amounts of free gas may be trapped beneath the base of the hydrate layer and suggest that low-permeability hydrated sediments can act as a seal for reservoirs.
GEOPHYSICS, VOL. 50, NO. 1